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# COMPUTER ANALYSIS OF 400 HZ AIRCRAFT ELECTRICAL GENERATOR TEST DATA


Philip G. Gaberdiel



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# COMPUTER ANALYSIS OF 400 HZ AIRCRAFT ELECTRICAL GENERATOR TEST DATA

THESIS

Presented to the Faculty of the School of Engineering
of the Air Force Institute of Technology
Air University
in Partial Fulfillment of the
Requirements for the Degree of
Master of Science

by
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## Preface

The purpose of this project was to develop software analysis and display systems for the Generator Test Facility of the Aero Propulsion Laboratory. This system is used to evaluate the performance of advanced aircraft electrical generating systems. The software systems presented in this thesis comprise a major portion of the test facility.

I would like to acknowledge the support and guidance given me by Joseph Walick, Engineering Technician, and William Borger, Project Engineer, both of the Aero Propulsion Laboratory. I would also like to thank my wife, Cherry for her effort in typing this thesis.

Philip G. Gaberdiel

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## Abstract

A software system was specified which would derive the performance measures of MIL-STD-704B from the test data provided by the Generator Test Facility. This analysis software system was then designed and implemented. Accuracy tests on the system demonstrated that very precise measurements of generator performance can be obtained.

A software system was also designed and implemented to display the analysis results to the user. The display system employs a Tektronix 4010 terminal in an interactive mode to present the data. The user, therefore, selects the particular display and time range to be presented.

COMPUTER ANALYSIS OF 400 HZ AIRCRAFT ELECTRICAL GENERATOR TEST DATA

# I. Introduction

## Background

The Generator Test Facility of the Aero Propulsion Laboratory is a computer-controlled facility for conducting performance tests on aircraft electrical generating systems. The facility has three 350 horsepower motors capable of providing generator drive speeds up to 30,000 rpm. Electrical loading for the generator under test is supplied by 5 passive load banks, each designed to provide 3-phase, infinitely variable loads with ratings up to 120 kva, 0.75-1.0 power factor. The test facility also includes oil and air systems for supplying cooling to the generator system.

Computer control of a generator test is provided by a Modcomp minicomputer and a set of test control software. The software enables the test engineer to program the minicomputer to control execution of the generator test. The minicomputer, via various input/output systems, (1) controls generator speed and acceleration rate, (2) selects load bank settings, and (3) performs other contact-closure type functions related to controlling the generator test. The minicomputer also monitors an array of safety conditions during generator testing. If any of these conditions exceed preset limits, the minicomputer invokes automatic test shutdown procedures.

In summary, a typical generator test consists of accelerating the generator to a specific operating speed and then applying a particular electrical load. Figure 1 illustrates the test control system of the Generator Test Facility. In order to determine the performance of the generator in response to a particular set of test conditions, the test engineer must examine the generator output during the test.

A method for examining the generator output is precisely the area in which other generator test facilities have had the most difficulties. Electrical measurement devices such as ammeters, voltmeters, oscilloscopes, oscillographs, etc. are used to display the generator output. These devices suffer from basic inaccuracies and slow response times. It is also difficult to synchronize the taking of data exactly with occurrence of the desired test conditions. Further, in order to examine all three phases of the generator output, it is often necessary to rerun a test several times. Generally the performance measurements which can be determined from the generator output are limited to those which can be displayed directly by an electrical instrument. In short, these methods for examining

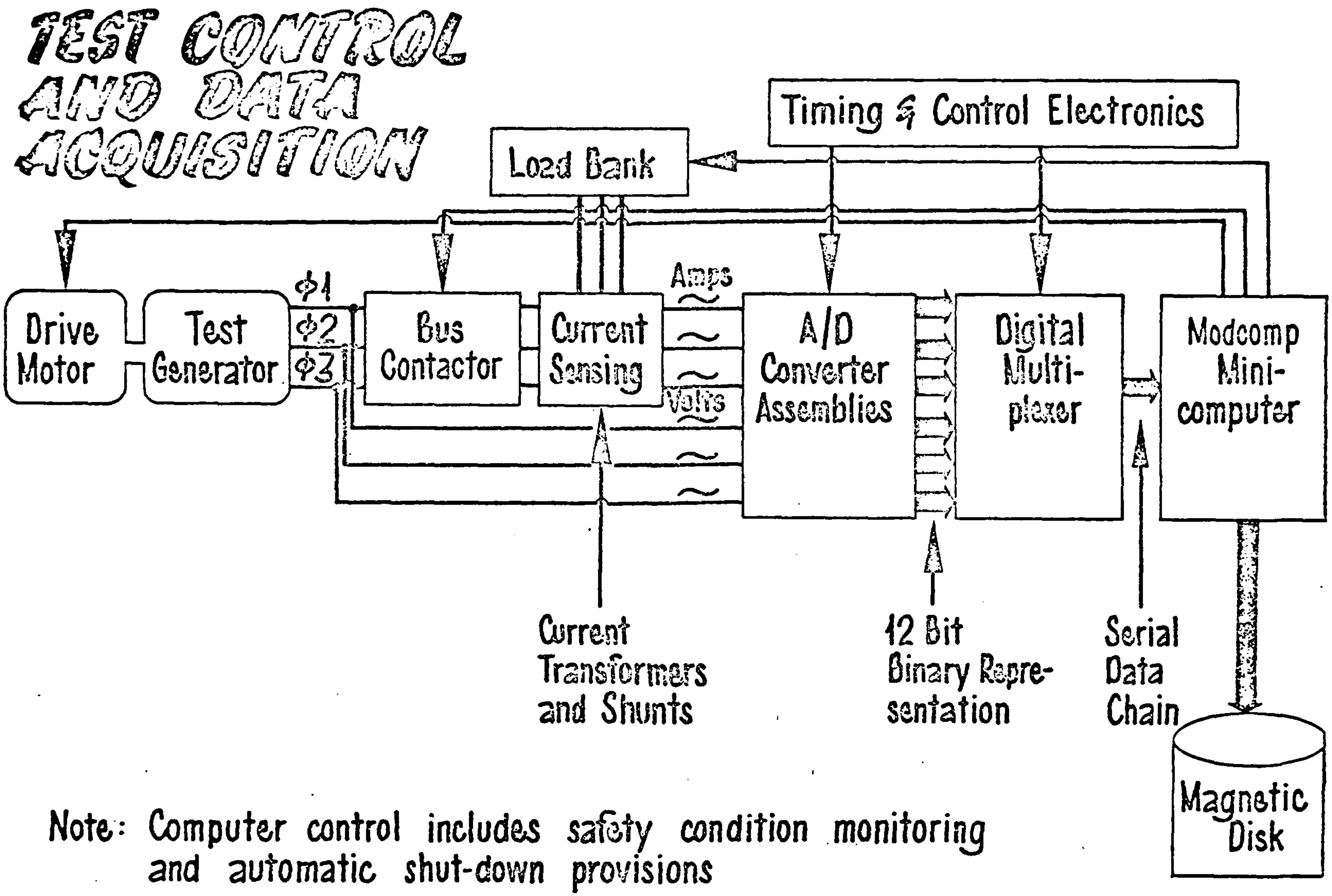



Figure 1. Test Control System

electrical generator performance suffer from inaccuracy and inability to adequately measure transient response, require considerable skill and patience on the part of the analyst, and are cumbersome and inconvenient.

The Generator Test Facility includes a high speed data acquisition system to facilitate the task of examining aircraft electrical generator performance. The data acquisition system is based on the following scheme. First, a low level (0-5 volt) a.c. signal is developed which is proportional to the electrical signal being measured. For generator phase voltage, a resistive voltage divider is used to reduce the nominal 115 volts to 5 volts. The phase current is first reduced to a lower current level by passing it through a step-down current transformer. This lower level current (usually 0-5 amps) is impressed across a resistive shunt to produce a millivolt signal proportional to the phase current. This millivolt signal is then amplified to the desired 0-5 volt level with an instrumentation amplifier.

The a.c. voltage signals proportional to the generator output are then each converted to a 12 bit binary representation by a high speed (4 microsecond conversion time) analog-to-digital conversion assembly. An electronics multiplexing assembly then formats these binary data words into serial blocks which each include a reference timing word. The output of the multiplexing electronics is available as input to the test facility minicomputer.

One function of test control performed by the minicomputer is to input and store the output of the data multiplexing system over the time range specified by the test engineer. The magnetic disk of the minicomputer is currently used as a storage device for the generator test data. Thus at the completion of a test, a digitized representation of the output of the generator in response to the test conditions is stored on a dedicated file of the minicomputer magnetic disk.

The data acquisition system is illustrated in Figure 2. The system, from analog-to-digital conversion to storage on the magnetic disk, operates at a rate of approximately 8800 hertz. This rate provides a new digitized data point every 113 microseconds or 22 data points per cycle of 400 hertz generator output.

A measure of the performance of the generator in response to the conditions of a test can be determined by examining this digitized test data directly. In order to provide a fuller description of the generator performance, numerical calculations can be performed using the digitized representation of generator output and the reference timing word as input. The results of these calculations display the performance of the generator more clearly to the test engineer.

The goal of this project was to design and implement a software system to analyze the data available from the Generator Test Facility.

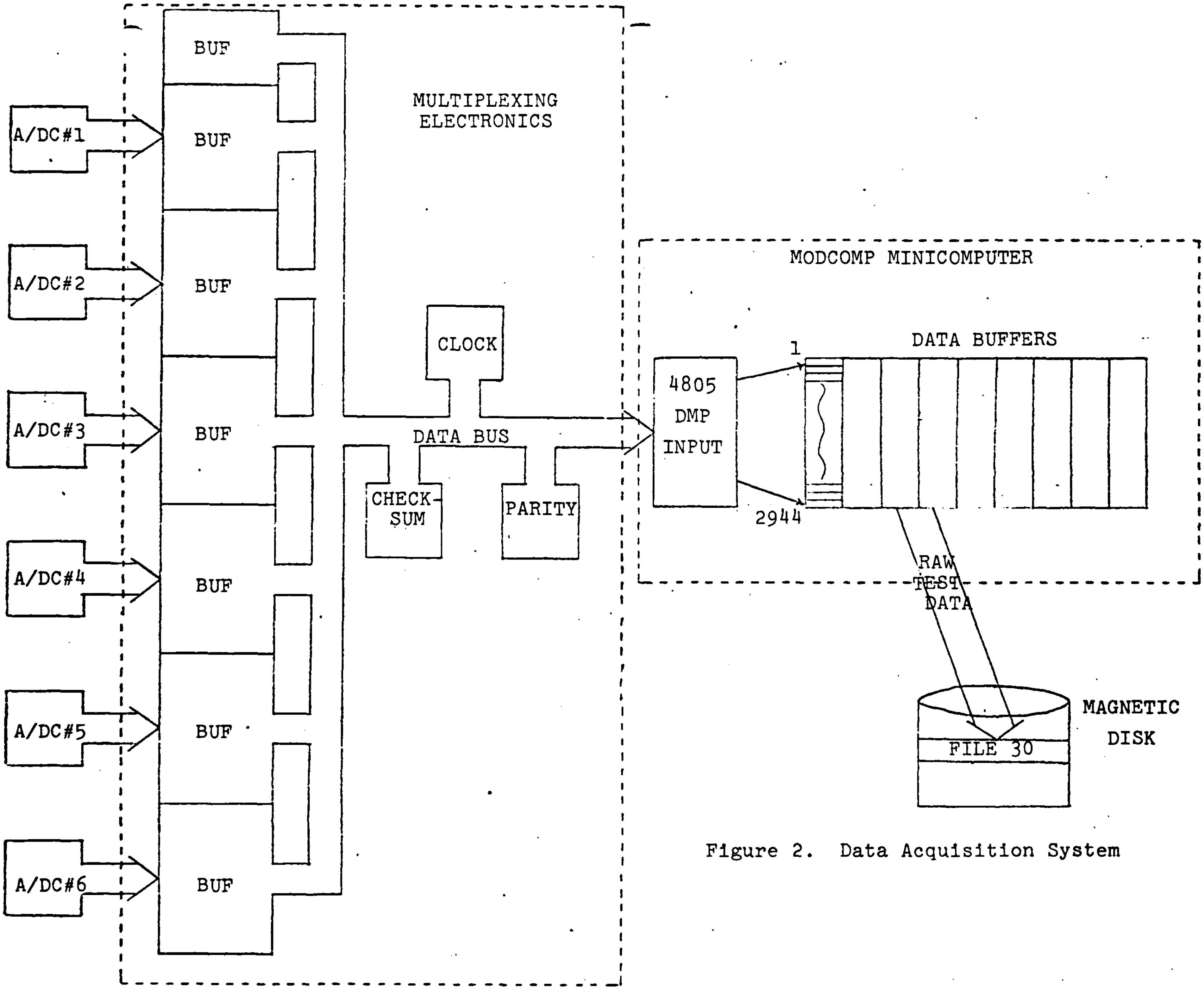



Figure 2. Data Acquisition System

## Objective

The objective of this project was to design and implement a software analysis system for the Generator Test Facility of the Aero Propulsion Laboratory. The input to this analysis system is the digitized data blocks produced by the data acquisition system of the test facility. The analysis system must produce a set of electrical measurement calculations which describe the performance of an aircraft electrical generator system in response to the conditions of the test.

The software system must also include display routines which allow the test engineer to examine the results of the analysis. These routines must be interactive so that the user can display any analysis results over any time range.

## Approach

This project was accomplished in the following manner. The first step was to specify a set of analysis computations to be performed on the generator test data. The results of these computations provide a measure of the performance of an aircraft electrical generation system in response to the conditions of the test. Military and industry electrical generator performance standards were used in selecting the particular set of analysis computations that were implemented.

After the analysis requirements were finalized, algorithms were chosen which would derive the selected computations from the generator test data available from the data acquisition system of the Generator Test Facility. In most instances, several algorithms were available to implement a particular analysis computation. In these cases, the particular algorithm chosen was selected by trading off ease of implementation, accuracy, and execution speed.

Next, a software system was designed to implement the required analysis computations using the algorithms selected in the previous step. This software design stressed an overall goal of structuring the system into individual modules each performing a distinct function. The design also emphasized high cohesion within each module and low coupling between modules. A software system which meets these design goals not only accomplishes the data analysis task but does so in a very straight forward manner. The well-designed software system is thus easy to maintain and therefore can expect a longer useful life.

The software system designed in the previous step was then implemented. Fully commented source listings of all routines were generated to document the software analysis system. A series of tests were conducted to determine the accuracy of the algorithms used in the analysis system. The next step of the project was to devise a method to present the analysis results to the user.

Therefore, next a software system was designed which displays the results of the data analysis to the test engineer. The output device used for this display is a Tektronix 4010 cathode-ray-tube terminal. The terminal's cross-hair cursor input feature is implemented to allow the engineer to select the particular analysis computation and time range to be displayed. Again, a structured design for the display software was derived to provide easy software maintenance. In addition to fully commented source listings for all display software, a user's manual was written to aid the test engineer.

The total software system, with both analysis and display features, provides the Generator Test Facility with a complete and very accurate mechanism for examining the performance of an aircraft electrical generator under test. The following text discusses each aspect of this thesis project in detail.

## II. Analysis Software System

### Requirements

The goal of the first phase of this project was to determine a set of analysis computations which would represent the performance of an aircraft electrical generation system. The set of performance parameters were limited to those dealing with electrical measurements of 400 hertz alternating current (a.c.) waveforms. By limiting the study to electrical measurements, mechanical measurements such as torque and heat output are specifically eliminated. These type measurements are useful in calculating system efficiencies; however, instruments to measure these parameters are not currently part of the Generator Test Facility.

By limiting the study to 400 hertz a.c. parameters, those dealing with direct current (d.c.) or wild frequency systems are specifically eliminated. Although those type of systems may have some value in future aircraft electrical systems, the management of the Aero Propulsion Laboratory is concentrating future development on 400 hertz a.c. systems.

The basic source for selecting this set of analysis computations is MIL-STD-704B, "Military Standard Aircraft Electric Power Characteristics".(Ref 1) This document defines standards for aircraft electrical power characteristics present at utilization equipment power-input terminals, maintained during operation of the generation equipment. The purpose of this standard is to provide voltage and frequency limits and conditions for aircraft electric power to be used as criteria for system performance.

Documents describing the analysis procedures used in the test facilities of several generator manufacturers (Ref 2,3) were examined to determine if their analysis requirements differ from those given in MIL-STD-704B. No new information or substantial differences in definition of terms were found in these reports. Therefore, the set of analysis computations which are used as design requirements for the analysis software system are derived from MIL-STD-704B.

The analysis requirements and definitions are as follows:

1. Frequency - Frequency is equal to the reciprocal of the alternation period of the fundamental of the a.c. voltage. The alternation period of the fundamental is assumed to be equal to the time difference between two successive negative-to-positive crossovers of the a.c. voltage. The unit of frequency is the number of alternations per second and is designated hertz (Hz).

2. A.C. Voltage - The term a.c. voltage refers to the root mean square (rms) phase to neutral values, where rms voltage is defined by the formula

$$V_{rms} = \sqrt{\frac{1}{T}\int_0^T v^2(t)\,dt} \qquad (1)$$

where

T = period of alternation

3. Distortion - A.C. distortion is the rms value of the a.c. waveform exclusive of the fundamental. A.C. distortion includes the components resulting from amplitude modulation as well as harmonic and non-harmonic components.

4. Distortion factor - The a.c. distortion factor is the ratio of the a.c. distortion to the rms value of the fundamental component of the waveform.

5. Distortion spectrum - The distortion spectrum quantifies a.c. distortion in terms of the amplitude of each frequency component. The distortion spectrum includes the components resulting from amplitude and frequency modulation as well as harmonic and non-harmonic components of the a.c. waveform.

6. Frequency transient - The frequency transient is the locus of values defined by the reciprocals of sequential alternation periods of the a.c. voltage, in instances when the frequency departs from the steady-state value.

7. Voltage surge - The voltage surge is defined as a transient departure of the peak values of

voltage from the peak instantaneous value of the steady state voltage, persisting for periods in excess of 500 microseconds, followed by recovery to within peak values corresponding to steady state. Surges are caused by load changes, switching, or power interruptions elsewhere in the system.

8. Voltage spike - The spike is a transient of total duration normally less than 500 microsecond and is superimposed on the otherwise unaltered instantaneous voltage. Because of the limited sampling rate of the Generator Test Facility, only spikes of approximately 250 microseconds or greater can be accurately measured. Spikes may be characterized in the time domain in terms of voltage with parameters of duration, risetime, and energy.

9. Voltage unbalance - Voltage unbalance is defined as the maximum difference among phase voltage magnitudes at the utilization equipment terminals.

10. Steady state - A steady state condition of a characteristic is one in which the characteristic shows only negligible change throughout an arbitrarily long period of time.

Following are several long-term (steady state) generator performance measurements.

11. Frequency drift - Frequency drift is the slow and random variation of the controlled frequency

level within steady state limits due to such influences as environmental effects and aging. When applicable, the time rate of frequency change due to frequency drift is the frequency drift rate.

12. Frequency modulation - Frequency modulation is defined as the difference between maximum and minimum values of 1/T, where T is the alternation period of one cycle of the fundamental of the phase voltage. When applicable, the rate at which 1/T values repeat cyclically is called the frequency modulation rate.

Long-term or steady state performance measurements of this type were not implemented in this project. This is because the present design of the Generator Test Facility allows storage of data for times of generally 10 seconds or less. The long-term measurements given above are normally computed over a much longer time frame. However, it should be noted that the transient (short-term) performance of a generator is more difficult to measure than the steady state (long-term) performance. It is the transient response which other generator test facilities have had the most problem measuring accurately. If in the future the data storage time span possible with the Generator Test Facility is increased, steady state measurements should be included as part of the analysis software system.

Two additional parameters must be determined from the generator test data in order to accurately describe the electrical conditions under which the generator is operating. These parameters describe the type and amount of electrical loading applied to the generator.

13. A.C. Current - A.C. current refers to the rms value of the phase current, where rms current is defined by

$$i_{rms} = \sqrt{\frac{1}{T}\int_0^T i^2(t)\,dt} \qquad (2)$$

where

T = alternation period of phase voltage

14. Power factor - Power factor is defined as the cosine of the phase angle between the voltage and the current of a particular phase of generator output. The phase angle defines the phase relationship between the voltage and current waveforms of a particular phase of generator output. This phase relationship is determined by the type of electrical load applied to the generator. Therefore, the power factor helps describe the electrical conditions under which the generator was operating during the test. The power factor of any phase of generator output is given by the following formula:

$$P.F. = \frac{\int_0^T v(t)i(t)\,dt}{\sqrt{\frac{1}{T}\int_0^T v^2(t)\,dt}\sqrt{\frac{1}{T}\int_0^T i^2(t)\,dt}} \qquad (3)$$

where

T = period

The next step of this project was to design a set of analysis software to derive the above-stated performance measures from the test data produced by the Generator Test Facility. First, however, design goals had to be specified for the accuracy of each analysis computation. These goals were determined by considering the types of analysis to be performed with the test facility and the built-in error present in the measurement circuitry.

A major function of the test facility is to compare the performance of aircraft electrical generating systems against their design requirements. The requirement specifications for several advanced generating systems (Refs 4,5,6,7) were reviewed. These systems are typically required to regulate steady-state voltage to $\pm 1$ volt rms and steady-state frequency to $\pm 1$ hertz. These requirements define the worst case error acceptable from the entire data acquisition system. In other words, the data acquisition system must be accurate enough to detect deviations of at least these magnitudes. Therefore, the design goal for the accuracy of the overall data acquisition and analysis system was chosen as $\pm 0.5$ volts rms for voltage measurements, $\pm 1.0$ amps rms for current measurements, and $\pm 0.5$ hertz for frequency measurements.

However, this overall accuracy is determined by several factors. For current measurements, the current transformer-shunt combinations contribute a possible worst case error of $\pm 0.517\%$ of full scale. This error represents $\pm 5.17$ volts for voltage measurements and $\pm 1.29$ amps for current measurements. Since this amount of inaccuracy is not acceptable, a detailed calibration procedure was devised for the overall measuring circuit. Use of the calibration procedure reduces the hardware measurement error to a negligible amount ($\pm 0.054$ volts and $\pm 0.023$ amps). Therefore, the accuracy specifications given for the overall measurement process were used as design goals for the analysis software.

Design

Before designing the software for the analysis software, algorithms were determined to compute each of the performance measures selected above. Following is a discussion of each performance measurement and the algorithm which is used to derive it.

1. Frequency - Frequency is computed as the reciprocal of the period of the voltage waveform. The period of the voltage is taken to be the time difference between successive positive-sloped zero crossovers of the waveform. However, the exact time of zero crossover is not known. This is because data sampling and the generator output are not synchronized. This unsynchronization means that data points which correspond with an exact zero crossover are not guaranteed (in fact they are extremely rare). Thus the exact time for a zero crossover must be estimated by interpolating

between the data point just prior to crossover and the data point just after crossover. Figure 3 illustrates the voltage waveform with data points marked with small triangles. Figure 4 presents the basis for the following linear interpolation used to estimate time of zero crossover.

$$Z_T = \frac{V_1}{V_1 - V_2}(T_2 - T_1) + T_1 \qquad (4)$$

Using this linear interpolation assumes that the voltage waveform will be very linear in the short time span between the known data points. This is a valid assumption since a pure sine wave is indeed very linear about a zero crossover. In fact using a data sampling period of 100 microseconds, calculations show that the worst case error in determination of zero crossover of a 400 Hz sine wave is 0.102 microseconds. This represents a theoretical worst case error of 0.0008% in the calculation of the period of the waveform. Determination of the actual period measurement error of the analysis software is presented later in this thesis.

Therefore, to represent frequency of a particular phase of generator output, values for the period of each cycle of the voltage waveform are determined using the method stated above. It is important that these period values be determined independently for each of the three phases of generator output. This is because the frequency of the individual phases

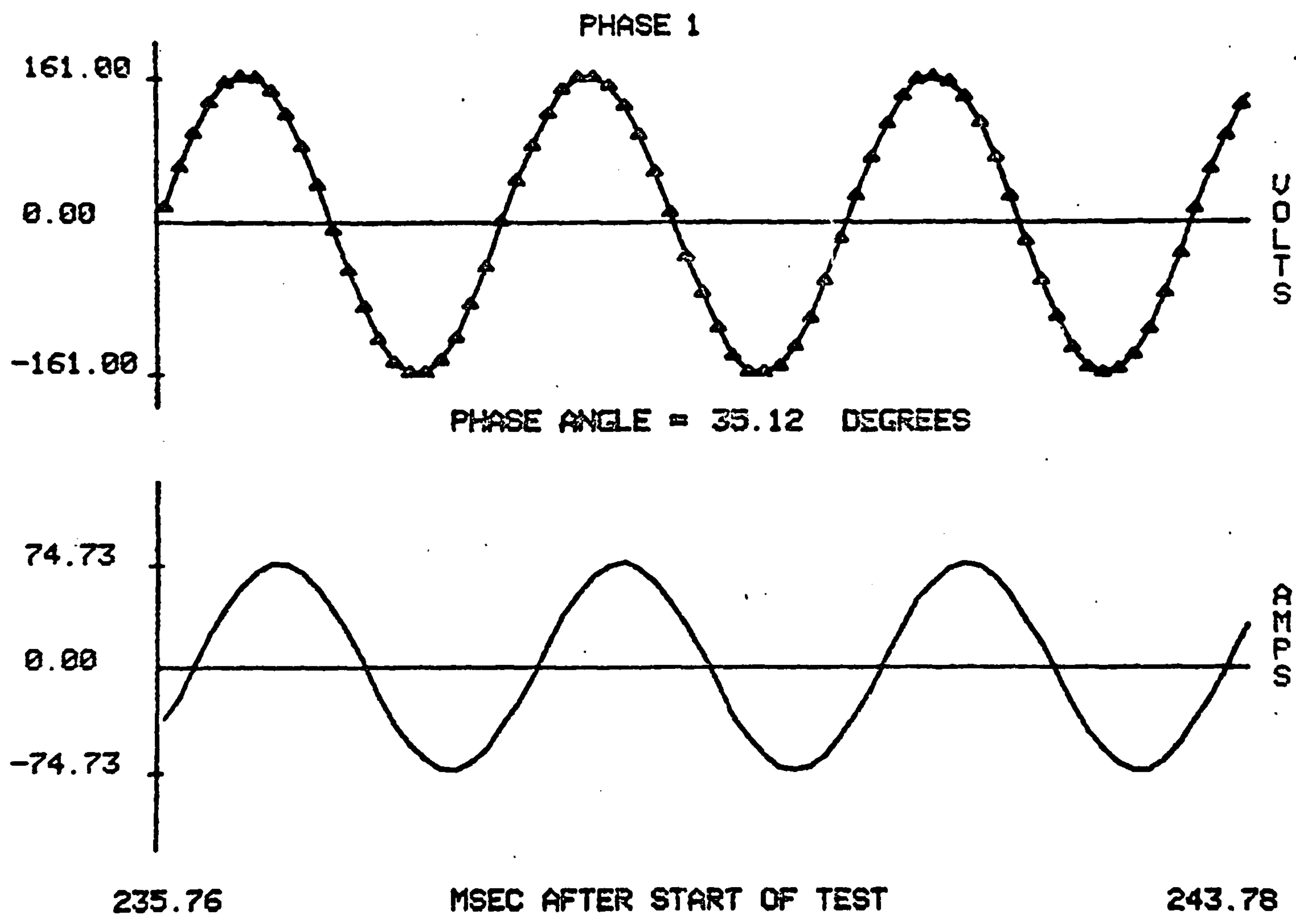



Figure 3. Voltage Waveform with Data Points

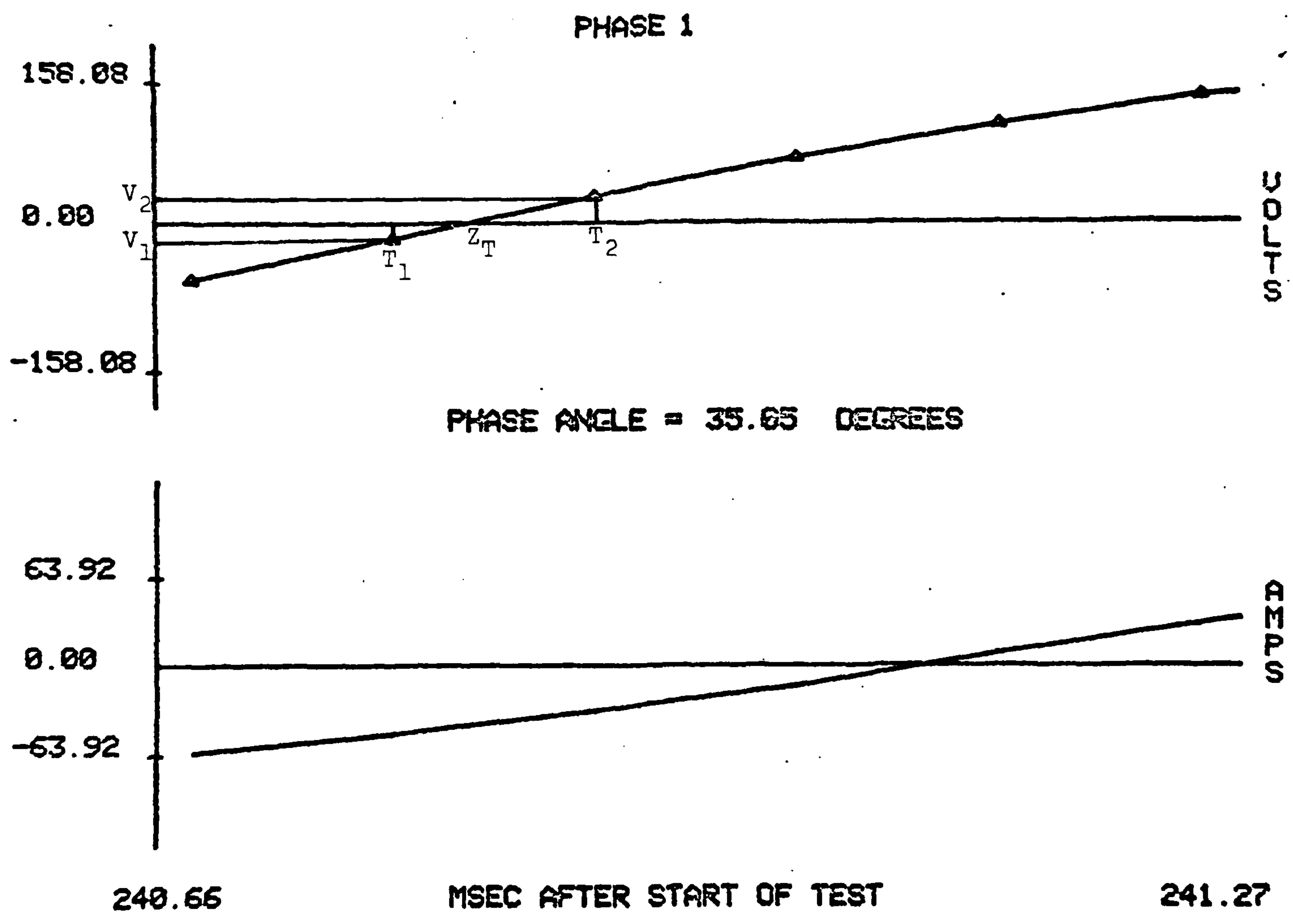



Figure 4. Zero Crossover Interpolation

of the generator output can be different.

2. RMS values - The root mean square (rms) value of each cycle of phase voltage must be computed. Equation 1 defines the rms value of voltage.

A numerical integration technique was devised which will compute the average (mean) value of the squared phase voltage data points over each cycle. The rms value is then found by taking the square root of this mean value.

In addition to rms voltage, the rms value of phase current is also computed over each cycle. This current value is useful in displaying the type of electrical load under which the generator was operating during the test.

The numerical integration technique used in rms calculations is a modified trapezoidal rule. The basic trapezoidal rule requires that data points be equally spaced. This requirement is met in the generator test data except around the zero crossovers which occur at the beginning, middle, and end of each cycle of the waveform. Over these time intervals of irregular width, the integral is determined by computing the triangular area under the waveform between the known data point and the estimated zero crossover. For all other time intervals, the normal trapezoidal rule is used. Equation 5 presents the implementation of Equation 1 using this modified trapezoidal rule for the voltage waveform represented in Figure 5.

$$V_{rms} = \sqrt{\frac{1}{PERIOD}\left(SUMA + SUMB + SUMC + SUMD + SUME\right)} \quad (5)$$

where

$$SUMA = \frac{V^2(t_1)}{2}(t_1 - Z_{t_1}); \text{ first zero crossover}$$

$$SUMB = \frac{t_{samp}}{2}\sum_{n=1}^{10}(V^2(t_{n+1}) + V^2(t_n)); \text{ positive half cycle}$$

$$SUMC = \frac{V^2(t_{11})}{2}(Z_{t_2} - t_{11}) + \frac{V^2(t_{12})}{2}(t_{12} - Z_{t_2}); \text{ middle zero crossover}$$

$$SUMD = \frac{t_{samp}}{2}\sum_{n=12}^{21}(V^2(t_{n+1}) + V^2(t_n)); \text{ negative half cycle}$$

$$SUME = \frac{V^2(t_{22})}{2}(Z_{t_3} - t_{22}); \text{ final zero crossover}$$

and

$$PERIOD = Z_{t_3} - Z_{t_1}; \text{ period of alternation}$$

$$t_{samp} = t_{n+1} - t_n; \text{ time between data samples}$$

A determination of the accuracy of this method for calculating the rms value of a waveform was performed. A routine implementing this modified trapezoidal rule was executed on a test input consisting of a software-generated 400 Hz sine wave with data points occurring every

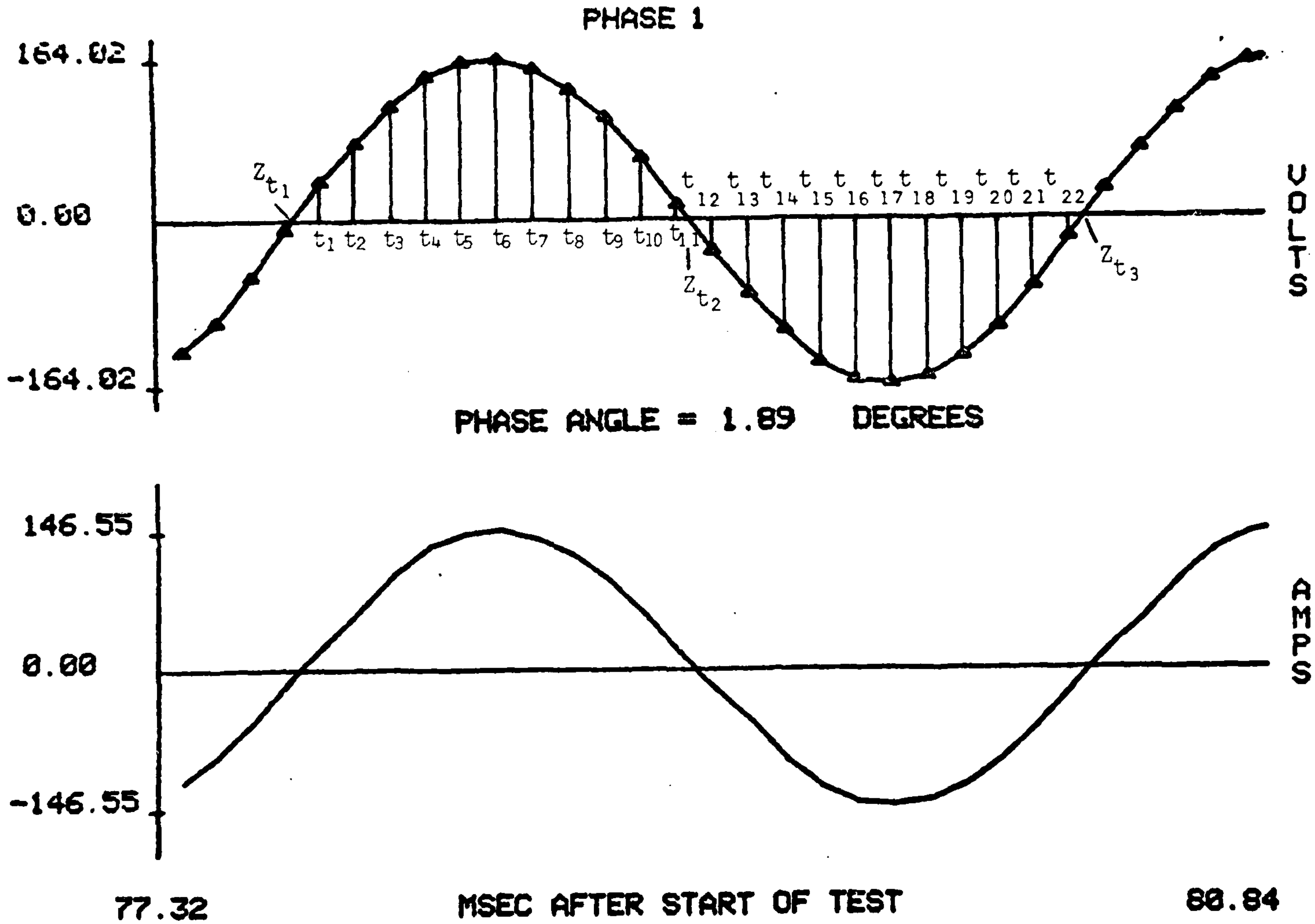



Figure 5. Numerical Integration

113 microseconds. This test input simulates very accurately the actual data available from the data acquisition system of the Generator Test Facility. The error in determining the rms value of the test input was found to be less than 0.04%. Determination of the actual voltage and current rms measurement errors of the analysis software is presented later in this thesis.

3. Power factor - A value for the power factor of each cycle of generator output is computed using the definition given in Equation 3. The numerical integration required in this equation is implemented using the modified trapezoidal rule defined in the discussion of rms values.

The preceding analysis computations - frequency, rms voltage, rms current, and power factor provide the information necessary to describe the performance of the electrical generator in response to the conditions of the test. Therefore the analysis software system processes the raw test data stored by the data acquisition system on a dedicated file of the minicomputer's magnetic disk and computes a value for each of the parameters for each cycle of each of the three phases of generator output over the entire test time. The results of this analysis are stored on another dedicated file of the magnetic disk. These results are then available to the display software for interactive presentation to the user.

Most of the remaining performance measurements selected as design requirements for the analysis software are available upon display of the basic analysis computations just discussed. Therefore, the display software must present these results in the proper formats to portray these measurements.

One final set of analysis computations have not been discussed. These are the computations dealing with the a.c. distortion of the generator output voltage waveform.

4. Distortion - Distortion of the voltage waveform is determined by computing its Fourier representation. The Fourier representation will accurately portray all distortion components in the waveform if an infinite number of harmonics are computed. However, because of the finite data sampling rate of the data acquisition system, the Fourier representation of the test data is accurate for only a limited number of harmonics.

The data sampling rate of the data acquisition system is approximately 8800 hertz. By using the Nyquist sampling criteria, waveforms of up to 4400 hertz can be accurately analyzed. Therefore, the Fourier analysis procedure computes up to the 11th harmonic of the output voltage waveform.

The Fourier series representation used for this measure of waveform distortion is given by the following equation.

$$f(t) = \frac{a_0}{T} + \frac{2}{T}\sum_{n=1}^{11}(a_n \cos w_n t + b_n \sin w_n t) \qquad (6)$$

where

$T$ = period and $w_n = \frac{2\pi n}{T}$

The magnitude of the frequency component at each harmonic is given by

$$\sqrt{a_n^{\,2} + b_n^{\,2}}$$

where

$$a_0 = \frac{2}{T}\int_0^T f(t)dt \text{ - the average value of the waveform}$$

$$a_n = \frac{2}{T}\int_0^T f(t)\cos\frac{2n\pi t}{T}\,dt \text{ - the cosine components} \quad (7)$$

$$b_n = \frac{2}{T}\int_0^T f(t)\sin\frac{2n\pi t}{T}\,dt \text{ - the sine components}$$

Harmonic analysis of the generator output voltage waveform is generally of interest only during portions of the test in which conditions are essentially steady-state. During changes in electrical load or acceleration/deceleration of the generator, the output voltage will usually contain waveform distortion which is not of interest. Therefore, the computation of Fourier coefficients is not carried out over the entire range of test data as for the rms and frequency calculations. Doing this would require storing a large amount of mostly useless data on the intermediate disk file.

Instead, computation of the Fourier coefficients is deferred until display of the test data. At this time, the user selects the particular time range over which the harmonic analysis is to be performed. Additionally, it is possible to determine the Fourier representation of each individual cycle of the voltage waveform. However, in order to compare the Fourier representation to those produced by instruments such as spectrum analyzers, it is usually more desirable to compute the magnitudes of the harmonic components based on an average over several cycles. The user also selects the number of cycles over which to carry out this computation. This completes the formulation of algorithms to derive the required calculations. Next, a software system was designed to implement these algorithms.

Figure 6 presents a top-level description of the software modules that comprise the analysis system. Basically, an executive routine drives three subordinate modules. One module handles input of the raw test data; one module performs the numerical analyses; and one module outputs the results to the storage device. The following section of this thesis presents the implementation of this software design.

## Implementation

A source listing for the analysis software system is presented as Appendix A. These routines implement the generator performance computations described earlier. Presented here is a brief explanation of this software.

The basic task of the system, illustrated in Figure 6, is to input the raw test data stored on the disk, calculate the specified performance measurements, and store the results

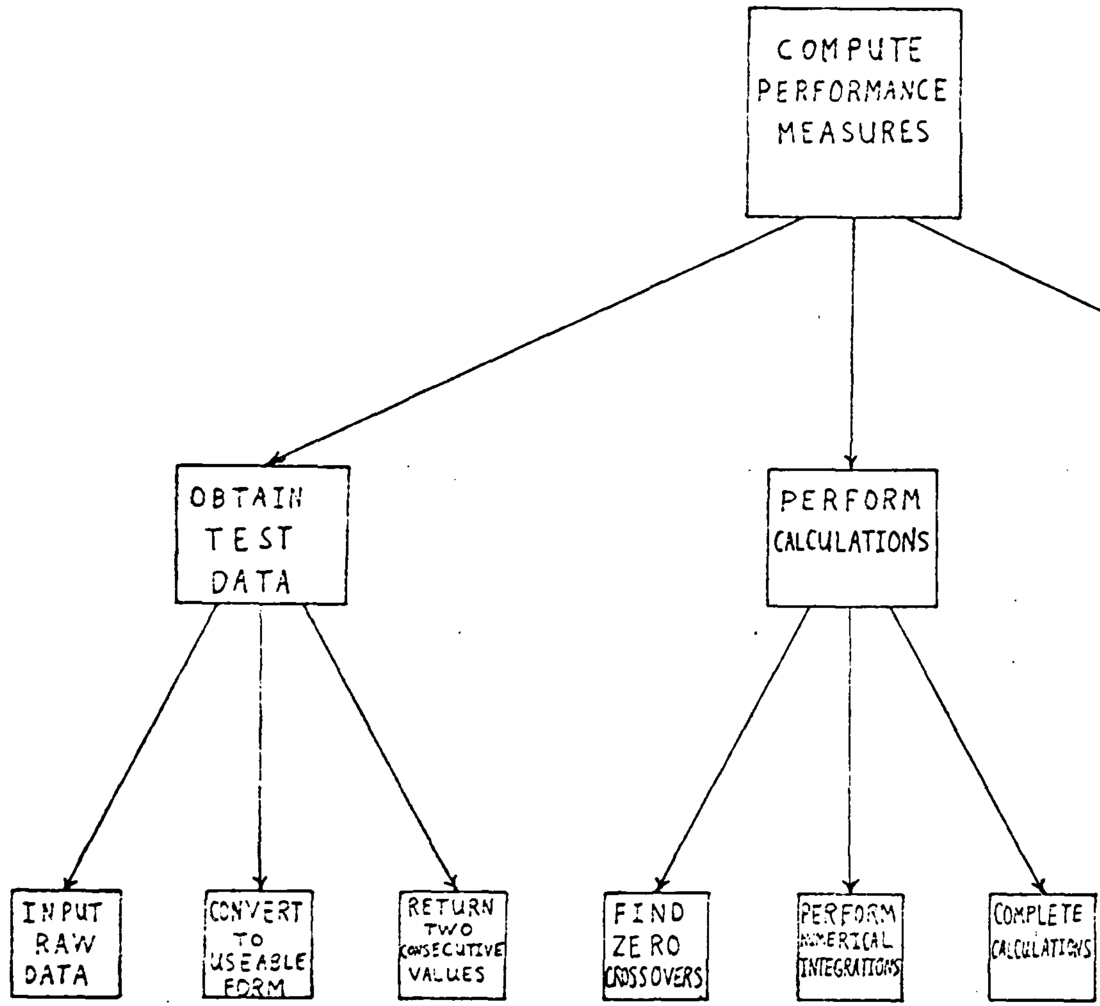



Figure 6. Analysis Software Design

back on the disk. These results are then available to the display software system.

To perform this data analysis process, first a root module ANALYSIS was written to direct three other modules which each perform a basic function. The first of these routines READA supplies two successive values of each phase voltage and current to the root module. These data values are floating point representations of the A/D converter outputs. Also returned is the time of the data sample measured from the beginning of data acquisition. The time values are "adjusted" double precision representations of the output of a reference clock circuit which is part of the data acquistion electronics.

On the first call to READA, the first two blocks of generator test data must be obtained for return to the root module. On all subsequent calls, only one new data block is obtained. The routine READA obtains each individual data block by calling the routine GETBLK.

The routine GETBLK performs the conversion of the raw test data to a form useable by the numerical integration routine. An explanation of the format of the raw test data is now in order. The output of the multiplexing electronics of the data acquisition system consists of a stream of 10-word blocks, each word being 16 bits wide. Figure 7 illustrates this data stream.

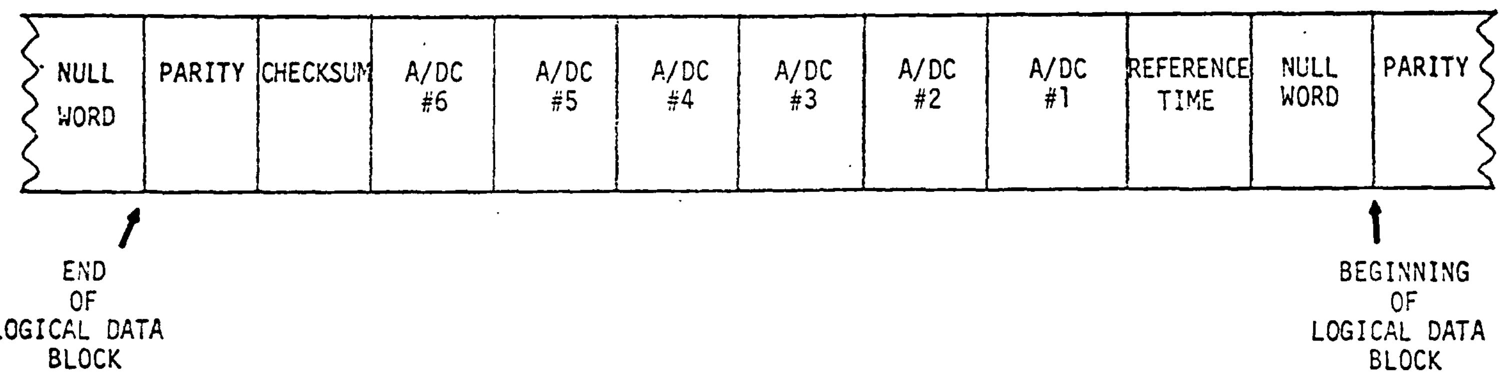



Figure 7 - Data Stream

The first word of a data block is a null input produced by a data buffer in the acquisition electronics which is hardwired to logic zero. This null word is used by GETBLK to locate the beginning of data blocks. The second word of the block is the output of a 16-bit counter driven by a 10 MHz crystal. (This counter has been referred to previously as the reference clock circuit.) This time signal is required for the numerical integration performed in the data analysis. The next six words of the data block are each the 12-bit binary output of one of the six A/D converters. The four low-order bits of the 16-bit data word are hardwired to logic one. The ninth word of the block is a parity word computed for the eight previous words of the block by an electronic circuit located in the data acquisition system. The final word is a checksum word also computed for the first eight words by the data acquisition electronics. These two data integrity words are used by diagnostic software which can exercise the data acquisition system to detect possible transmission errors.

These 10-word data blocks are stored sequentially on a file of the magnetic disk during test execution. The routine GETBLK must access each data block, convert it to useable form, and supply it to the routine READA. GETBLK performs this task in the following manner. On the initial call, the raw data is scanned to find the first null word which marks the beginning of the first full data block. Next, the reference timing word is processed. This timing word is produced by a 16-bit counter which resets to zero approximately every 13 milliseconds. Therefore the routine GETBLK keeps track of these "roll-overs" so as to provide a constantly increasing reference time. The time signal is also converted to double precision.

Next, each A/D converter reading is input and converted to floating point. This conversion consists of (1) multiplying by a factor which converts the 12-bit binary to floating point, (2) adding a zero offset value, and (3) multiplying by a scale factor to convert the A/D converter reading to equivalent volts or amps. The zero offset values and scale factors are computed for each A/D converter during a pre-test calibration procedure.

And, finally, GETBLK advances past the two data integrity words. Thus upon the next call to GETBLK, the data file should be positioned on a null word which marks the beginning of the next data block.

The routine READ30 handles the task of inputting each data word from the disk. READ30 returns the next sequential word from the data file on each successive call until an end-of-file mark is detected. An end-of-file flag is then set which signals the routine ANALYSIS that all raw test data has been processed. In addition, the initial call to READ30 rewinds the disk file and initializes all variables. Thus, this three-level set of routines supplies data values to the routine ANALYSIS.

The routine ANALYSIS then passes these data values to the routine which carries out the numerical integrations required to implement the calculations described earlier in Section II. This routine is named NUMINT. A basic description of this routine is as follows. Since all of the numerical integrations must be performed over one complete cycle, the routine must detect positive-sloped zero crossovers which mark the beginning and end of a cycle. Thus the routine first searches the voltage values until it finds the beginning of a cycle. On each successive call, it accumulates the summations necessary to compute the integrals required in the calculations. When the end of a cycle is detected, the various calculations are completed and these values are returned to the routine ANALYSIS.

Each phase of test data must be processed separately. An independent integration range is required for each of the three phases of generator output data. This is due to the possibility of their slightly different frequencies noted earlier. The integrations involving phase currents are performed over the same time range as the corresponding phase voltage.

By processing each phase of data independently, no assumptions are made concerning the phase relationship or frequencies of the individual phases. This generality would allow 400 Hz data to be examined on one channel, 60 Hz data on another, and possibly d.c. on another. This flexibility is generally not needed for standard generator performance tests, but it is quite useful in the analysis of other types of electronic systems.

Once ANALYSIS receives a completed set of analysis computations (indicated by flag values), it must place these results on a storage device for later use by the display system. ANALYSIS calls the routine DWRITE to accomplish this.

The routine DWRITE sequentially outputs each packet of analysis results along with a key denoting the phase which the data represents to a dedicated file of the magnetic disk. The assembly code routine WRIT29 is called to write each data word to the disk file. The routine DINIT is called by ANALYSIS to rewind this file at the beginning of analysis. The routine DWEOF is called to close the data file when ANALYSIS determines that all test data has been processed.

The final step of the implementation of the analysis software system was to perform accuracy measurements. The following section discusses the results of these accuracy tests.

## Accuracy Measurements

As part of the design requirements for the analysis software system, error limits were specified. These limits were $\pm 0.5$ volts rms for voltage measurements, $\pm 1.0$ amps rms for current measurements, and $\pm 0.5$ hertz for frequency measurements. The algorithms selected to compute rms values and period measurements were shown to have theoretical errors much less than these goals. However, to provide complete assurance of the accuracy of the analysis software, two operational tests of the system were conducted.

The first test involved applying the analysis system to a software-generated input. This test input was provided by substituting the lowest level data handling routine, GETBLK, with a routine which supplied calculated sine function values so as to simulate actual generator test data. This test is very similiar to the software testing which was performed on the individual algorithms during their selection; however, this represents a more complete test of the accuracy of the analysis system. The test input was selected to be a 400 Hz sine wave with peak magnitude of 162.61 volts. The calculated results should then be 115 volts rms and 400 Hz. Actual results of the analysis with this test input are displayed in Figure 8. As can be seen, calculated values for rms voltage and rms current differ from the expected results by at most +0.1 unit. This error is well within the design limits. The values for frequency are exact to one decimal place. However, since in this case data sampling and the data waveform are essentially synchronized, this test does not adequately measure the accuracy of the frequency calculation.

The other accuracy test performed with the system consisted of performing analysis on a known electrical input.

PHASE 1

EACH ENTRY REPRESENTS AN AVERAGE OF 1 READINGS

| RMS VOLTAGE (VOLTS) | RMS CURRENT (AMPS) | FREQUENCY (HZ) | PF | TIME (SEC) |
|---|---|---|---|---|
| 115.0 | 115.0 | 400.0 | 1.000 | 0.029998 |
| 115.0 | 115.0 | 400.0 | 1.000 | 0.032498 |
| 114.9 | 114.9 | 400.0 | 1.000 | 0.034998 |
| 114.9 | 114.9 | 400.0 | 1.000 | 0.037498 |
| 114.9 | 114.9 | 400.0 | 1.000 | 0.039998 |
| 114.9 | 114.9 | 400.0 | 1.000 | 0.042498 |
| 114.9 | 114.9 | 400.0 | 1.000 | 0.044998 |
| 114.9 | 114.9 | 400.0 | 1.000 | 0.047498 |
| 114.9 | 114.9 | 400.0 | 1.000 | 0.049998 |
| 114.9 | 114.9 | 400.0 | 1.000 | 0.052498 |
| 114.9 | 114.9 | 400.0 | 1.000 | 0.054998 |
| 114.9 | 114.9 | 400.0 | 1.000 | 0.057498 |
| 114.9 | 114.9 | 400.0 | 1.000 | 0.059998 |
| 114.9 | 114.9 | 400.0 | 1.000 | 0.062498 |
| 114.9 | 114.9 | 400.0 | 1.000 | 0.064998 |
| 114.9 | 114.9 | 400.0 | 1.000 | 0.067498 |
| 114.9 | 114.9 | 400.0 | 1.000 | 0.069998 |
| 114.9 | 114.9 | 400.0 | 1.000 | 0.072498 |
| 114.9 | 114.9 | 400.0 | 1.000 | 0.074998 |
| 114.9 | 114.9 | 400.0 | 1.000 | 0.077498 |
| 114.9 | 114.9 | 400.0 | 1.000 | 0.079998 |
| 114.9 | 114.9 | 400.0 | 1.000 | 0.082498 |
| 114.9 | 114.9 | 400.0 | 1.000 | 0.084998 |

Figure 8. Accuracy Test - Simulated Input

This input was supplied by a 400 Hz reference power supply. The voltage output of the source was measured by a true rms voltmeter having an accuracy of $\pm 0.008$ volts. This voltage output was measured to be 128.4 volts rms. The frequency of the source was measured by a frequency counter to be exactly 400 hertz.

Figure 9 presents the results derived by the analysis software system for this test input. The average value of the calculated rms voltage over the time range displayed is 128.54. This differs from the measured value by +0.14 volts. The average value for frequency is 399.93 hertz. This differs from the measured value by -0.07 hertz. These error magnitudes are well within the design limits.

No error determinations for current measurements were performed as part of this test. This was because the method for developing current measurements makes it difficult to obtain an accurate ammeter reading for the current. However, the results of the previous test using a software-generated input insures that the analysis system will compute rms current with the required accuracy.

Thus, these two tests demonstrate that the analysis software system performs with the accuracy specified in the design goals. This level of accuracy makes the test facility and analysis system precise tools for determining generator performance measures. Next, a means was required to present the analysis results to the user. The next chapter discusses

PHASE 1

EACH ENTRY REPRESENTS AN AVERAGE OF 1 READINGS

| RMS VOLTAGE (VOLTS) | RMS CURRENT (AMPS) | FREQUENCY (HZ) | PF | TIME (SEC) |
|---|---|---|---|---|
| 128.7 | 2.1 | 400.1 | 0.077 | 0.028455 |
| 128.4 | 1.5 | 399.8 | 0.107 | 0.030954 |
| 128.5 | 1.6 | 399.9 | 0.237 | 0.033455 |
| 128.4 | 2.1 | 400.0 | 0.346 | 0.035956 |
| 128.3 | 1.5 | 399.8 | 0.070 | 0.038456 |
| 128.4 | 1.6 | 400.0 | 0.243 | 0.040958 |
| 128.4 | 1.5 | 399.8 | 0.035 | 0.043458 |
| 128.5 | 1.6 | 400.2 | -.165 | 0.045959 |
| 128.5 | 1.6 | 399.8 | 0.026 | 0.048458 |
| 128.7 | 1.6 | 400.1 | 0.024 | 0.050959 |
| 128.5 | 1.5 | 399.8 | 0.038 | 0.053459 |
| 128.7 | 1.5 | 400.0 | 0.031 | 0.055960 |
| 128.3 | 1.6 | 399.7 | -.032 | 0.058460 |
| 128.5 | 2.4 | 399.9 | 0.032 | 0.060962 |
| 128.6 | 1.6 | 399.9 | 0.072 | 0.063462 |
| 128.8 | 1.5 | 400.1 | 0.014 | 0.065962 |
| 128.7 | 1.7 | 400.1 | 0.134 | 0.068462 |
| 128.7 | 1.5 | 399.9 | -.258 | 0.070951 |
| 128.7 | 1.4 | 400.8 | 0.361 | 0.073468 |
| 128.6 | 1.6 | 399.8 | 0.351 | 0.075953 |
| 128.5 | 2.2 | 400.0 | 0.191 | 0.078464 |
| 128.5 | 1.7 | 399.9 | 0.281 | 0.080964 |
| 128.6 | 1.7 | 399.9 | 0.285 | 0.083465 |

Figure 9. Accuracy Test - Test Input

the display software system which was developed to serve this function.

## III. Display Software System

### Requirements

The next major task in this project was to implement a set of display software. This software allows the test engineer to examine the performance measurements derived by the analysis software system. The first step in developing this software system was to specify its design requirements.

Following are the design requirements for the display software selected with concurrence of the laboratory sponsor for this project. First, the display system must be interactive so that the user can select the desired display option, display time range, and particular phase of generator test data. The output device used to implement the display was a Tektronix 4010 terminal with hard-copy option. Its cross-hair function was used to provide the user a method of interactive response.

Next, a set of display formats were selected which would present the generator performance measurements in a clear and concise manner.

Following is a list of the selected formats:

1. Instantaneous values (plot) - This display presents the instantaneous values of a selected phase voltage and current versus time over the time range

selected by the user. The actual plot is generated by connecting the individual A/D converter readings. A value for the average power factor is computed over the displayed time and presented on the plot.

2. Instantaneous values (table) - This display presents in tabular form the instantaneous voltage, current, and time values of a selected phase over a selected time range. The values displayed are the scaled A/D converter readings and the "adjusted" output of the reference timer.

3. RMS values (plot) - This display presents the rms values of a selected phase voltage and current versus time over the time range selected by the user. This plot is generated by connecting the rms values computed by the analysis software.

4. RMS values (table) - This display presents in tabular form a value for rms voltage, rms current, power factor, period, and test time for each cycle of the selected phase over a selected time range.

5. Frequency deviation - This display plots the frequency versus time for a selected phase over a selected time range. By centering the plot about 400 Hz (the nominal frequency for generator output), this plot will display frequency deviation. Presented in the same display is a plot of rms phase voltage versus time. This plot is for reference

purposes and usually demonstrates the cause for any frequency deviation.

6. Harmonic content - This display presents a histogram of the magnitudes of each integral harmonic of the base frequency. This harmonic analysis is performed for the number of harmonics, over the number of cycles, and for the phase selected by the user. Values for the base frequency and total harmonic distortion are computed and displayed.

To make the display system easy to use, the user should generally be able to select any of the display options after the display of any other. In several instances, this is not possible. In particular, the harmonic content calculation and display will be available only after plotting the instantaneous phase values. Only from the phase values display can the user select meaningful parameters necessary for the harmonic analysis computation.

Also since the two tabular displays have no time scale associated with them, these displays can not be used for selecting another option. Therefore after the display of one of the tabular options, a display which has a time scale must be generated before further plot options can be selected. This display was chosen to be a summary plot of the entire test as represented by rms values versus time of all six data channels over the full time range.

This concludes the discussion of the design requirements specified for the display software system. A set of required display options has been selected. The general user/software interfaces have also been presented. The next step in implementing the display software was to design a system of software modules to satisfy these requirements.

## Design

The design of the display software lends itself very well to a modular approach. Figure 10 illustrates the structure of the display software system. First, a root module directs operation of the entire system. Submodules perform the actual implementation of the display. Two modules allow the user to specify the display option, phase, and time range of the next plot. Then a separate module generates the plot for each display option. Access to both the raw test data and the analysis results is required. The same routines which were used by the analysis system to access the raw test data are used by the display system. New routines are required to access the analysis results.

## Implementation

The source listings for all routines used in the display software system are included as Appendix B. Following is a brief discussion of this software. Much of the explanation of this software is deferred to the display system user's manual included as Appendix C.

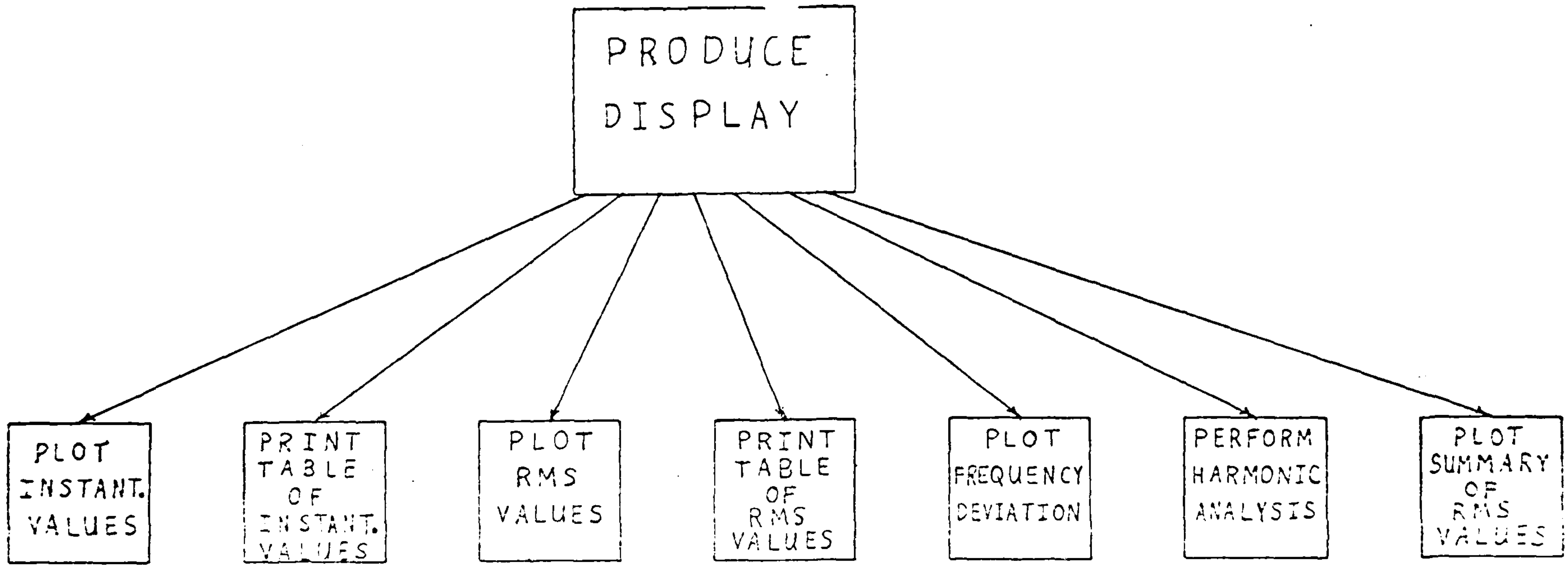



Figure 10a. Display Software Design

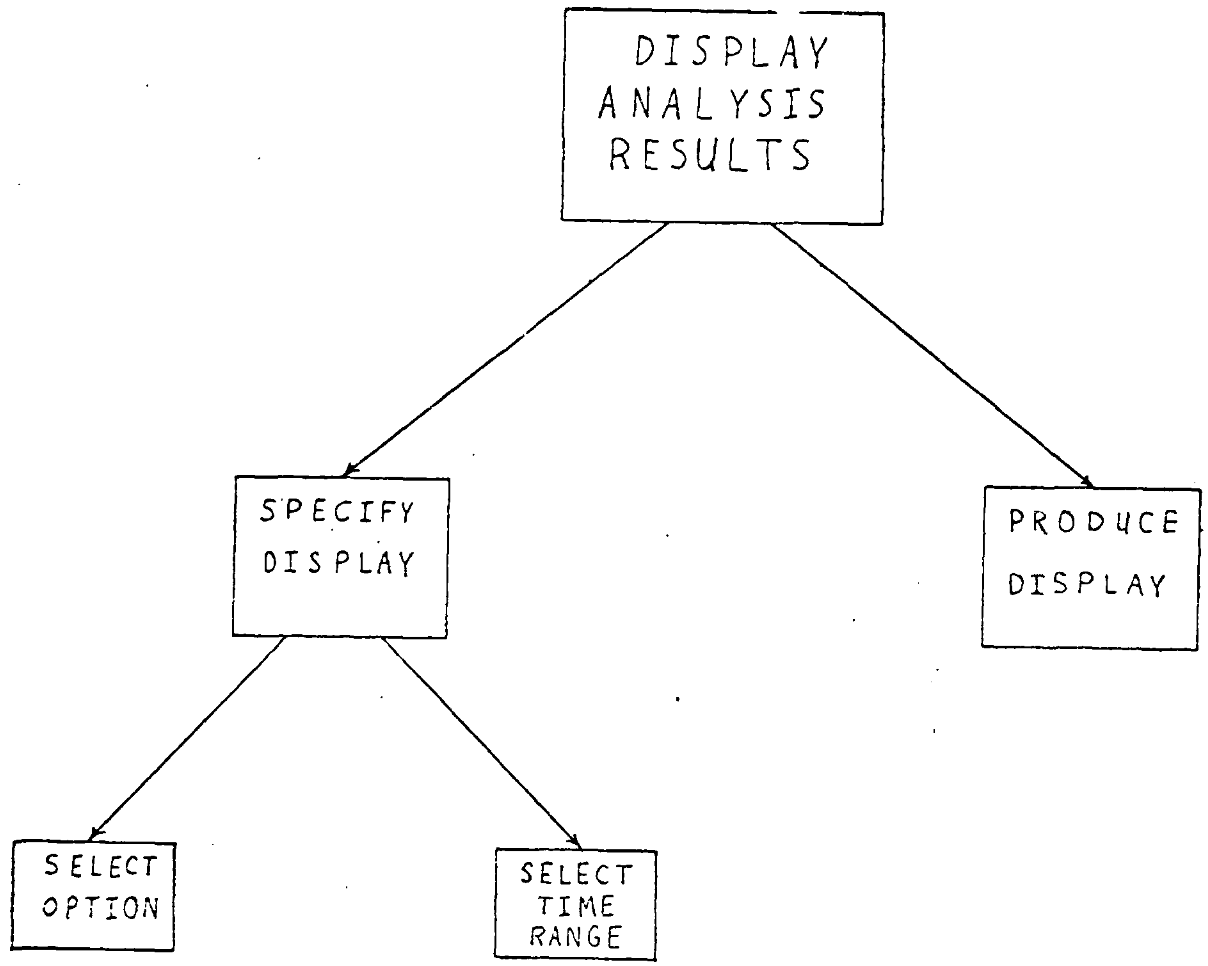



Figure 10b. Display Modules

The root module DISPLAY, as commanded by user responses, directs overall operation of the display system. The user is prompted to provide the responses which control execution of the display. First, the user is given the option of executing the routine ACSPEED. This routine determines the data sampling rate by calculating the frequency of the voltage waveform and counting the average number of data points present in several cycles.

Next the routine QKPLOT is executed which produces a summary plot of all rms values over the entire test range. An averaging scheme is employed so that only 100 points are plotted for each signal. This summary plot is used initially to select further plot options and time ranges with which to examine the generator performance. This plot is also used after either of the tabular displays have been presented or whenever a larger display time range is required.

After presentation of the summary plot, the routine PICKOPT enables the user to select one of the plot options. The routine PICKTIME allows the user to select the beginning and ending times over which to present the selected display. The Tektronix Plot-10 subroutine VCURSR is invoked for use of the crosshairs of the terminal. The parameters selected by the user define the next display.

The display options and the routine which implements them are presented in Figure 11. A complete explanation of each option and its use are included in the user's manual.

| OPTION | | DESCRIPTION | ROUTINE |
|---|---|---|---|
| IS | – | Plot of chosen phase rms voltage and current over selected time range. | ISOLATE |
| PR | – | Table of chosen phase rms values over selected time range. Provision for 1-9 readings to be averaged before printout. | PRINTVAL |
| CY | – | Plot of instantaneous values of chosen phase over selected time range. Average power factor over time range is displayed. | PLOTCY |
| PC | – | Table of instantaneous values of chosen phase over selected time range. | PRINTCY |
| FQ | – | Plot of frequency deviation of chosen phase over selected time range. Plot of rms phase voltage over time range is also given. | FREQDEV |
| QK | – | Summary plot of all three phases of rms values. Values are averaged to produce 100 points. | QKPLOT |

Figure 11. Display Options

Each display routine calls various Tektronix Plot-10 subroutines to produ required display. Figures 12-18 illustrate these display formats. Each plot is labelled to allow easy interpretation of the data, normally with the maximum values and the starting and ending test times represented in the display. In initial plots, default values must be used in setting the display screen dimensions. Therefore, some parameters may be plotted "off screen". Later displays will use the proper screen dimensions which have been determined during earlier plotting.

Thus the user interactively controls the display software system to produce displays of the generator performance during the test. Fully commented source listings of all routines used by the display software system (excluding the Plot-10 routines) are included as Appendix B. A complete user's manual describing the use of the display system is included as Appendix C.

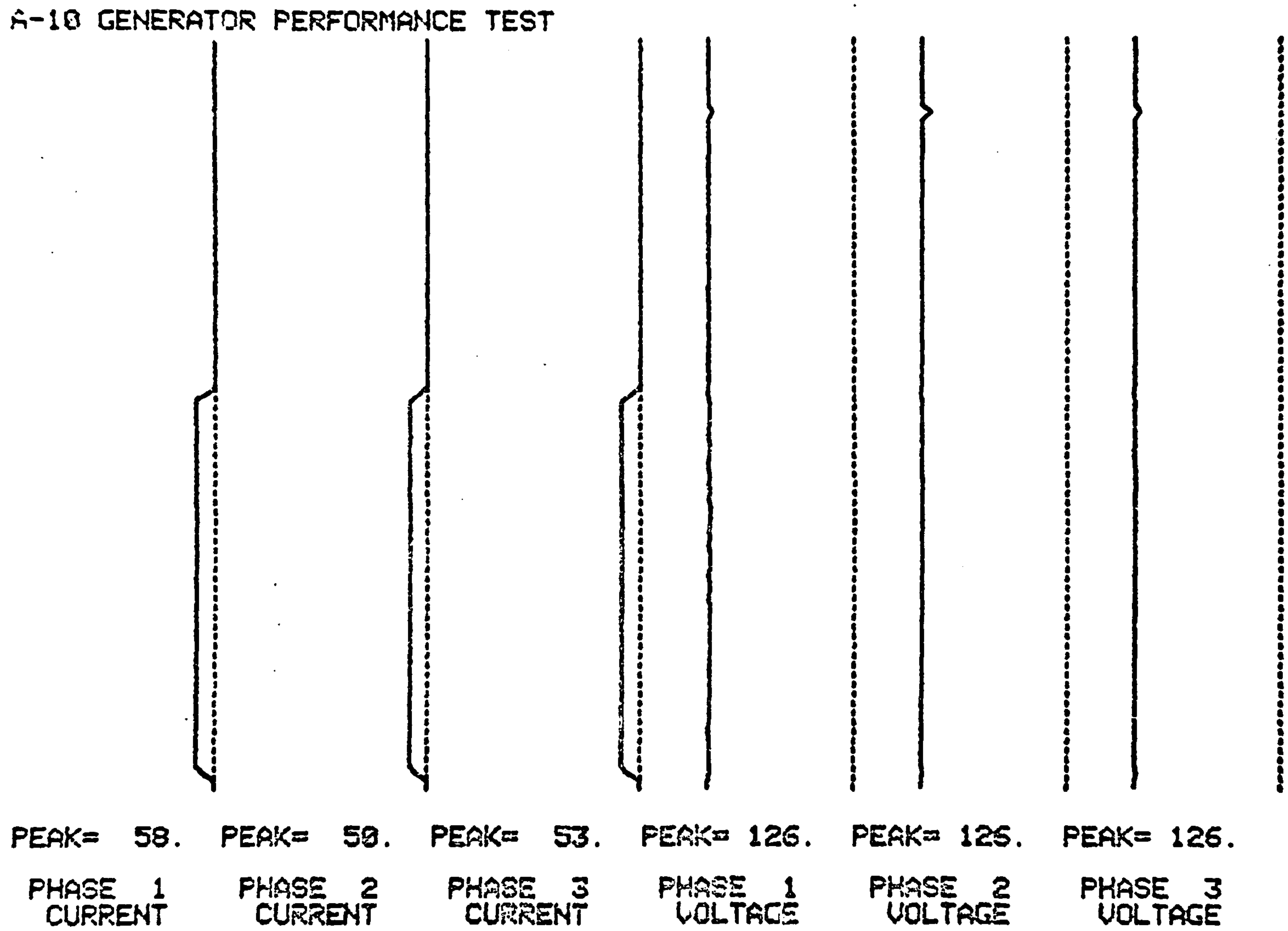



Figure 12. Test Summary Plc

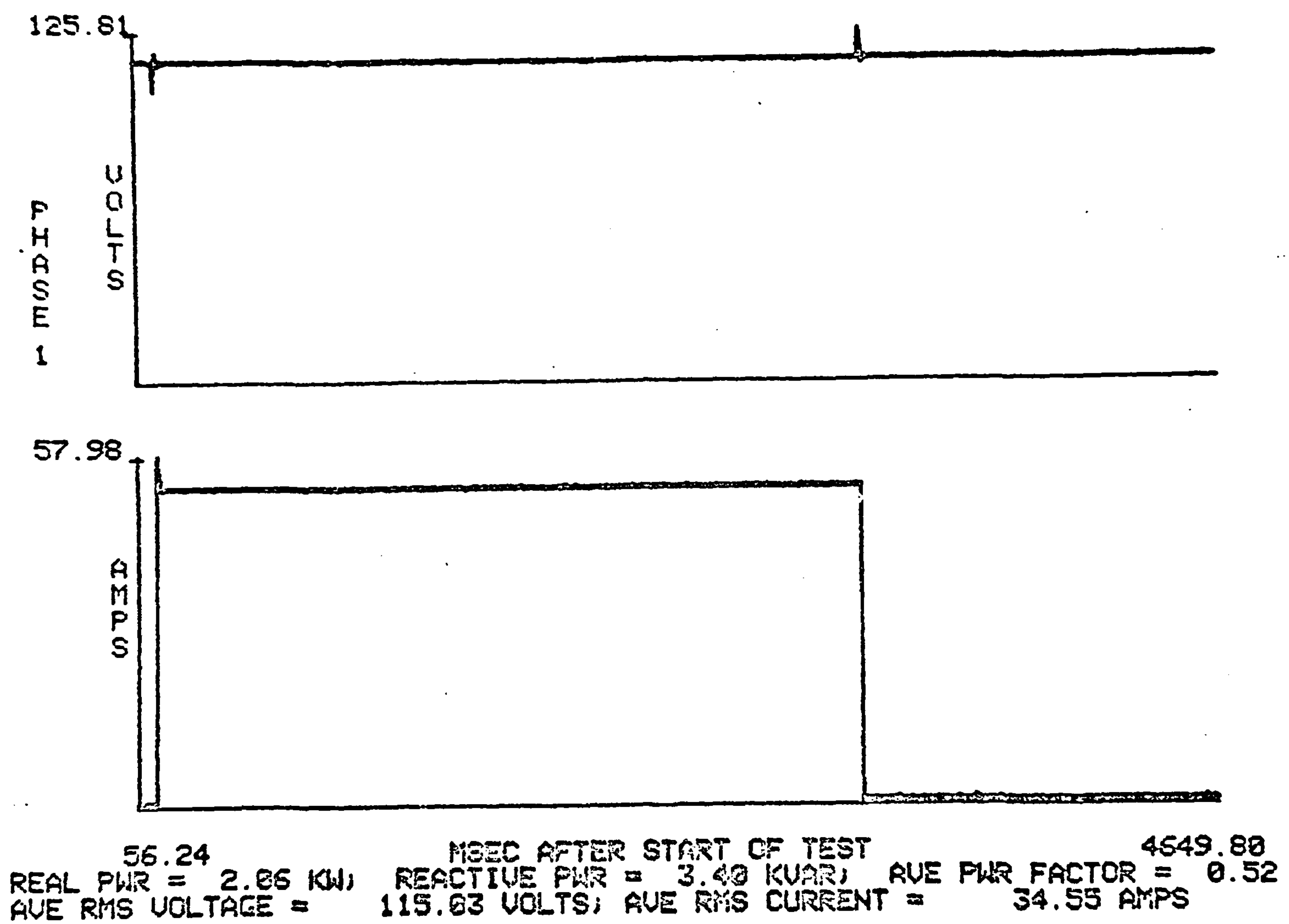



Figure 13. RMS Values Plot

PHASE 1

EACH ENTRY REPRESENTS AN AVERAGE OF 1 READINGS

| RMS VOLTAGE (VOLTS) | RMS CURRENT (AMPS) | FREQUENCY (HZ) | PF | TIME (SEC) |
|---|---|---|---|---|
| 115.2 | 52.5 | 399.6 | 0.819 | 0.293867 |
| 115.0 | 52.6 | 399.5 | 0.819 | 0.296389 |
| 115.1 | 52.5 | 399.1 | 0.819 | 0.298917 |
| 115.0 | 52.5 | 399.4 | 0.819 | 0.301442 |
| 115.1 | 52.5 | 399.5 | 0.818 | 0.303964 |
| 115.0 | 52.5 | 399.4 | 0.820 | 0.306493 |
| 115.2 | 52.6 | 399.1 | 0.818 | 0.309016 |
| 115.0 | 52.5 | 399.9 | 0.817 | 0.311540 |
| 114.9 | 52.5 | 399.4 | 0.815 | 0.314066 |
| 115.0 | 52.6 | 399.3 | 0.818 | 0.316589 |
| 114.9 | 52.5 | 399.8 | 0.817 | 0.319112 |
| 115.0 | 52.5 | 399.3 | 0.817 | 0.321639 |
| 115.1 | 52.6 | 399.1 | 0.818 | 0.324162 |
| 114.9 | 52.4 | 399.6 | 0.816 | 0.326687 |
| 115.0 | 52.6 | 399.5 | 0.820 | 0.329215 |
| 115.0 | 52.5 | 399.3 | 0.818 | 0.331737 |
| 115.0 | 52.5 | 399.7 | 0.818 | 0.334260 |
| 115.0 | 52.7 | 399.4 | 0.819 | 0.336787 |
| 115.0 | 52.4 | 399.3 | 0.817 | 0.339310 |
| 114.8 | 52.5 | 399.8 | 0.818 | 0.341833 |
| 115.0 | 52.5 | 399.5 | 0.819 | 0.344360 |
| 115.0 | 52.5 | 399.3 | 0.818 | 0.346882 |
| 114.9 | 52.6 | 399.8 | 0.818 | 0.349406 |

Figure 14. RMS Values Table

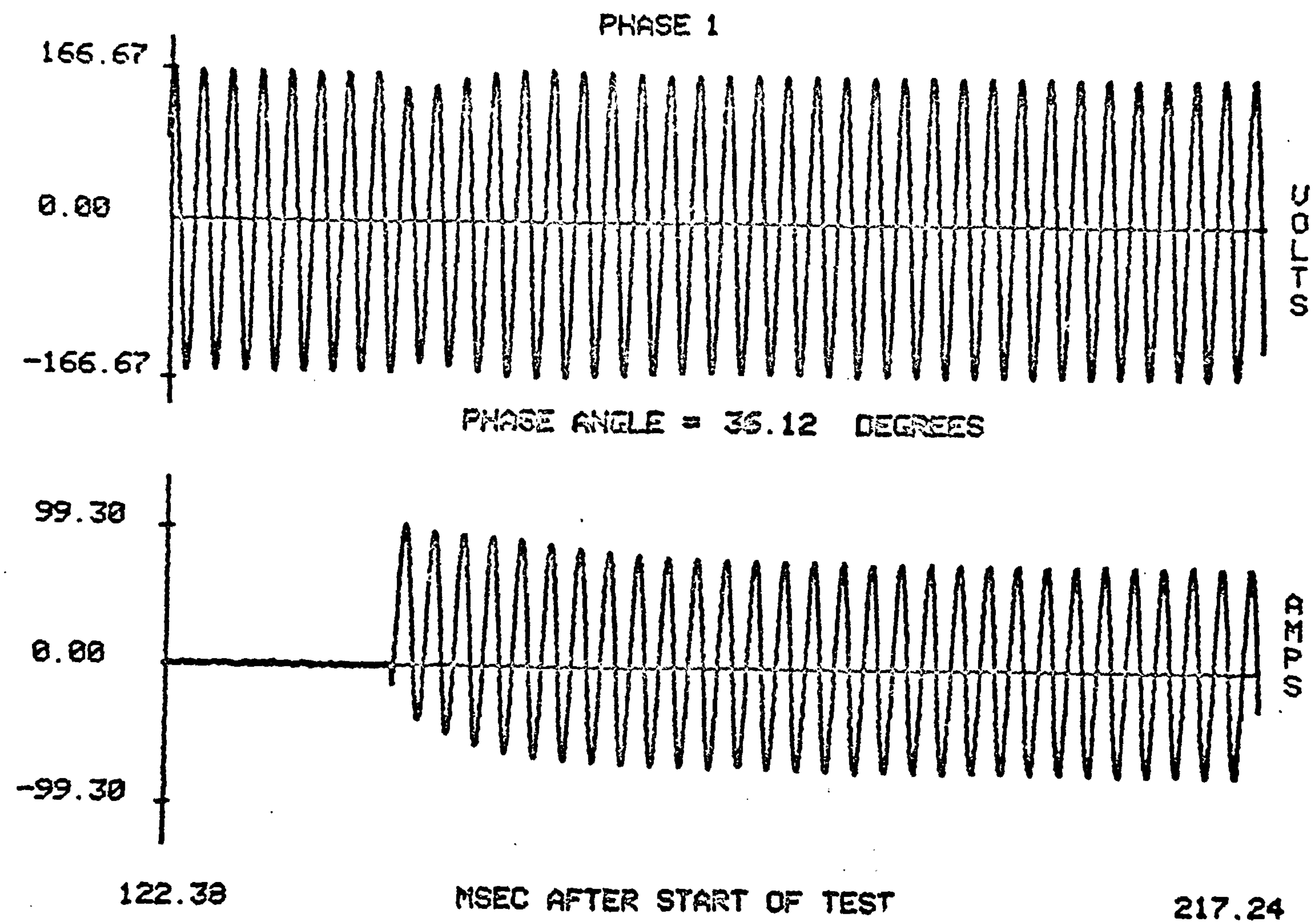
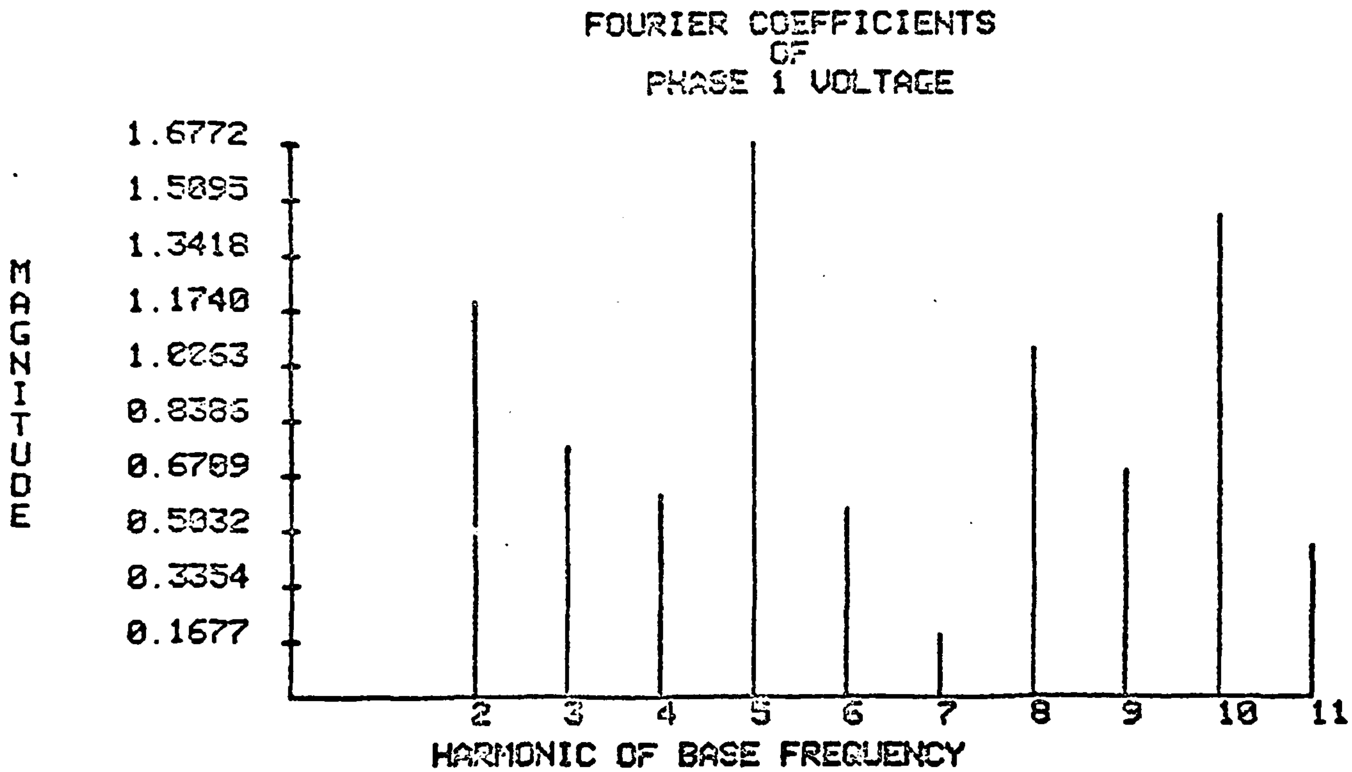



Figure 15. Instantaneous Values Plot

PHASE 1

| VOLTAGE | CURRENT | TIME |
|---|---|---|
| 161.5 | 60.4 | 0.329845 |
| 155.1 | 69.1 | 0.329958 |
| 138.6 | 72.7 | 0.330071 |
| 110.4 | 72.1 | 0.330184 |
| 71.5 | 64.3 | 0.330297 |
| 27.8 | 51.0 | 0.330410 |
| -18.9 | 34.7 | 0.330523 |
| -61.7 | 17.2 | 0.330636 |
| -99.1 | -5.0 | 0.330749 |
| -132.6 | -27.0 | 0.330862 |
| -155.0 | -45.3 | 0.330975 |
| -161.3 | -59.6 | 0.331088 |
| -157.4 | -69.0 | 0.331201 |
| -141.9 | -74.5 | 0.331314 |
| -116.1 | -74.4 | 0.331427 |
| -78.2 | -67.2 | 0.331540 |
| -34.9 | -54.9 | 0.331653 |
| 12.2 | -38.5 | 0.331766 |
| 56.5 | -21.4 | 0.331879 |
| 92.9 | -1.0 | 0.331992 |
| 127.9 | 21.5 | 0.332105 |
| 153.2 | 40.6 | 0.332218 |
| 161.5 | 55.8 | 0.332331 |
| 159.1 | 67.4 | 0.332444 |
| 145.9 | 72.3 | 0.332557 |
| 121.1 | 72.7 | 0.332670 |

Figure 16. Instantaneous Values Table




NOTE: BASE FREQUENCY IS 396.80 HZ
MAGNITUDE OF COEFFICIENT = 162.7291
TOTAL HARMONIC DISTORTION = 0.0133
DC CONTENT = 344.6503 MV

Figure 17. Harmonic Content

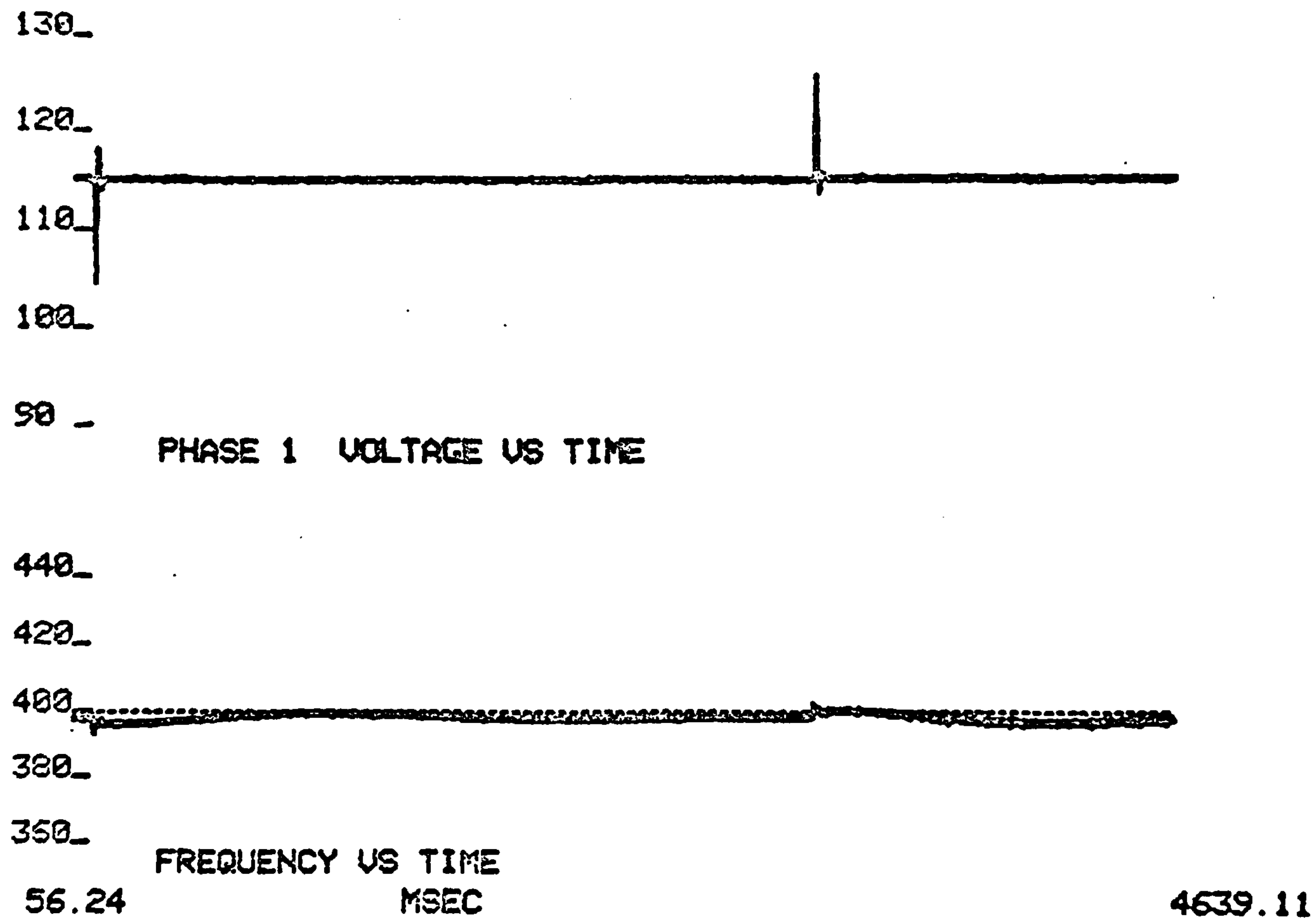



Figure 18. Frequency Deviation

## IV. Conclusions

In order to adequately discuss conclusions about the two software systems developed in this project, one must draw some conclusions about the Generator Test Facility itself. This test facility represents the most advanced system in the United States for conducting performance testing of aircraft electrical generating systems. Representatives from all leading generator manufacturers and other government agencies have witnessed operation of the facility and attest to its uniqueness.

Several factors distinguish this test facility from others like it. Computer control of the test facility allows a wide variety of different test conditions to be conducted and requires a minimum of personnel for operation. Computer control also facilitates safety monitoring of the test generator system.

The use of high speed analog-to-digital (A/D) converters represents a significant improvement in the acquisition of the generator test data. The fast conversion time of the A/D electronics provides the capability of examining relatively high speed transients in the generator output. Conversion of the analog representations of the generator output to digital format allows a wide range of sophisticated analysis techniques to be applied to the data.

This thesis project involved implementing a set of analysis computations to be performed on the generator test data. The selected set of computations derives numerical measures of the performance of an electrical generator in response to conditions of a test. Experience with the test facility has shown it to be a very valuable research and development tool. Extensive series of tests have been completed on several advanced aircraft electrical generator systems. The results of these tests have shown Air Force engineers aspects of the systems' performance which were previously unavailable. The two software systems developed during this project are critical components of the Generator Test Facility. They provide the facility with the analysis and display mechanisms necessary to make it a useful test tool.

The software systems themselves exhibit several distinguishing features. The accuracy of the analysis software system has been demonstrated. This accuracy was attained by implementing precise algorithms in careful programming to achieve the computations. The value of this accuracy is that great confidence can now be placed in the test results.

The structure of the analysis software itself is significant. The top-down, modular approach used in designing the software resulted in a very understandable and straight forward system. The system is easy to maintain and easy to update. As a result, the test facility is able to not only fulfull its original mission but also can be restructured to serve other test functions. To date, the test facility and analysis system have been used for electric motor testing and aircraft power controller testing. These tests required some specialized analysis routines, but the modular design of the analysis software allowed them to be added easily. In summary, the distinguishing features of the analysis software system are its accuracy and modular design.

The display software system also has several distinguishing features. Foremost is the straightforward manner in which the displays are presented. The displays present the generator performance measures in formats which are clearly labelled and easy to understand. In fact, hard copies of the display plots have been used to produce viewgraphs for presentations to upper level management about both the test facility, itself, and the generator systems under test. Additionally, hard copies of the display presentations are used directly in the technical reports written to describe the performance of the generator system under test.

The interactive control of the display system is also noteworthy. By issuing prompt messages, the software instructs the user in his selection of the display formats. In addition, a comprehensive user's manual was written for the display system. As evidence of the ease of using the display software, the engineering technician of the test facility has been trained to use the display system.

Again, the display software was modularly designed and implemented. This type of design provides easy software maintenance and update. This feature should prove very useful. The addition of a new display format will involve writing a new routine to provide the display and linking it into the system. Thus the system can be kept current to meet the needs of examining any new type of generation system.

## Bibliography


1. Military Standard Aircraft Electric Power Characteristics, MIL-STD-704B (17 Novermber 1975).

2. Test Procedure for 150 KVA Electrical Power Generating System, Sundstrand Model 150IDG02, Component Improvement Program, Contract Number F 33657-71-C-0810, Sundstrand Aviation Corporation (23 July 1971).

3. Power System Evaluation Test, Data Recording and Reduction System, T6-5813-1, The Boeing Company (October 1974).

4. Wall, Marly B. Electrical Power System of the Boeing 767 Airplane.

5. Electrical Generating System, VSCF. General Electric Company (September 1979).

6. General Specification for Aircraft Electric Generating System, Variable Speed Constant Frequency. MIL-E-23001B(AS). (28 June 1976).

7. General Specification for Aircraft Generator System, 400 Hertz Alternating Current. MIL-G-21480A(AS). (30 September 1970).

# Appendix A

# Analysis Software

```
      PROGRAM ANALYSIS
C
C  THIS ROUTINE COMPUTES THE RMS VALUES OF EACH OF THREE PHASES
C  OF VOLTAGE AND CURRENT.  THE AVERAGE REQUIRED IN THE RMS
C  CALCULATION IS PERFORMED USING A NUMERICAL INTEGRATION
C  TECHNIQUE OVER THE PERIOD OF THE VOLTAGE OF EACH PHASE.
C
C
      DIMENSION VAL1(20),VAL2(20),RMS(20),PF(3)
      DOUBLE PRECISION CYTHK(3),PER(3),TIM1,TIM2
      INTEGER PHASON(3),BUFULL(3),EOF
C  RESERVE LOCATION AT WHICH TO OVERLAY DISPLAY ROUTINE
      INLINE
BIAS    EQU $
      FINI
C  CHOOSE INTEGRATION RANGE
      WRITE(8,200)
200   FORMAT(' ENTER NUMBER OF CYCLES OVER WHICH TO'
     1,/,' INTEGRATE, I1')
      READ(7,300)L
300   FORMAT(I1)
C  INITIALIZE DISK FILE FOR RESULTS
      CALL DINIT
C  INITIALIZE FLAGS TO INDICATE NUMERICAL INTEGRATION HAS NOT BEGUN

      DO 5 NPH=1,3
      PHASON(NPH)=0
C  INIT. FLAGS TO INDICATE IF VALID RMS VALUE EXISTS
5     BUFULL(NPH)=0
```

```
C   SET NUMBER OF A/D CONVERTERS IN USE
        NADC=6
C   INITIALIZE RAW DATA FILE
        CALL GETBLK(N,N,N,2)
C   SET FLAG TO INDICATE BEGINNING OF DATA
        EOF=2
C   GET TWO SETS OF DATA
10      CALL READA(NADC,VAL1,VAL2,TIM1,TIM2,EOF)
C   CHECK IF END OF DATA WAS ENCOUNTERED
        IF(EOF.EQ.1)GO TO 50
C   PROCESS PHASE 1 DATA
        CALL NUMINT(1,VAL1,VAL2,TIM1,TIM2,PHASON,BUFULL,RMS,CYTM,PER,
PF,L)
        IF(PHASON(1).EQ.0)GO TO 10
C   CHECK IF RMS VALUE FOR PHASE 1 EXISTS
        IF(BUFULL(1).EQ.0)GO TO 20
C   WRITE CALCULATED VALUES TO DISK
        CALL DWRITE(1,RMS(1),RMS(4),PF(1),PER(1),CYTM(1))
C   RESET PHASE 1 FLAG
        BUFULL(1)=0
C   PROCESS PHASE 2 DATA
20      CALL NUMINT(2,VAL1,VAL2,TIM1,TIM2,PHASON,BUFULL,RMS,CYTM,PER,
PF,L)
C   CHECK IF RMS FOR PHASE 2 EXISTS
        IF(BUFULL(2).EQ.0)GO TO 30
C   WRITE CALCULATED VALUES TO DISK
        CALL DWRITE(2,RMS(2),RMS(5),PF(2),PER(2),CYTM(2))
C   RESET PHASE 2 FLAG
        BUFULL(2)=0
C   PROCESS DATA FOR PHASE 3
30      CALL NUMINT(3,VAL1,VAL2,TIM1,TIM2,PHASON,BUFULL,RMS,CYTM,PER,
PF,L)
C   CHECK IF RMS FOR PHASE 3 EXISTS
        IF(BUFULL(3).EQ.0)GO TO 10
```

```
C  WRITE CALCULATED VALUES TO DISK
       CALL DWRITE(3,RMS(3),RMS(6),PF(3),PER(3),CYTM(3))
C  RESET PHASE 3 FLAG
       BUFULL(3)=0
C  GET NEXT SET OF DATA
       GO TO 10
50     CALL DWEOF
C  LOAD OVERLAY ROUTINE,DIS, WHICH DISPLAYS ANALYZED DATA
C  BIAS IS ADDRESS TO LOAD DIS AT
       INLINE
         LDI,2  BIAS
         REX,023
         DFC  ERROR
         DFC  @LM
         DFC  @DIS
         DFC  @
         BRU OUT
ERROR  REX,#13
         DFC  @DIS
OUT      NOP
       FINI
       STOP
       END
C
C
       SUBROUTINE NUMINT(NPH,V1,V2,T1,T2,PHON,BUFULL,RMS,CYTM,PER,PF
,NCY)
C
C  THIS ROUTINE CARRIES OUT THE SUMMATION NECESSARY TO COMPUTE THE
C  RMS VALUES OF EACH PHASE OF GENERATOR TEST DATA INDEPENDENTLY.
C
       DIMENSION ZV(3),V1(1),V2(1),RMS(1),SUM(6),PEAK(3),PF(1)
      1,ZT1(3),ZT2(3),PERIOD(3),PFSUM(3)
       DOUBLE PRECISION CYTM(1),T1,T2,PER(1)
```

```
      INTEGER PHON(1),BUFULL(1),UNDX,CYKNT(3)
C  DERIVE VOLTAGE INDEX
      UNDX=NPH+3
C  CHECK FOR POSITIVE ZERO CROSSING OF VOLTAGE
      IF((V1(UNDX).LE.0.).AND.(V2(UNDX).GT.0.))GO TO 20
C  SEE IF INTEGRATION HAS BEGUN FOR THIS PHASE
      IF(PHON(NPH).EQ.0)RETURN
C  UPDATE PEAK VALUE
      IF(V2(UNDX).GT.PEAK(NPH))PEAK(NPH)=V2(UNDX)
C  CHECK FOR NEGATIVE Z. CROSS. OF VOLT.
      IF((V1(UNDX).GE.0.).AND.(V2(UNDX).LT.0.))GO TO 80
C  NOT A Z. CROSS; EVALUATE FULL TRAPEZOID
      SUM(UNDX)=SUM(UNDX)+(V1(UNDX)**2+V2(UNDX)**2)*TDEL
C  CHECK FOR POS. Z. CROSS. OF CURRENT
10    IF((V1(NPH).LE.0.).AND.(V2(NPH).GT.0.))GO TO 90
C  CHECK FOR NEG. Z. CROSS. OF CURRENT
      IF((V1(NPH).GE.0.).AND.(V2(NPH).LT.0.))GO TO 90
C  NOT A Z. CROSS.; EVALUATE FULL TRAPE.
      SUM(NPH)=SUM(NPH)+(V1(NPH)**2+V2(NPH)**2)*TDEL
C  UPDATE POWER FACTOR SUM
      PFSUM(NPH)=PFSUM(NPH)+(V1(UNDX)*V1(NPH) + V2(UNDX)*V2(NPH))
     1*TDEL
      RETURN
C  CHECK IF THIS IS BEGINNING OF INTEGRATION
20    IF(PHON(NPH).EQ.0)GO TO 50
C  COMPUTE TIME OF FINAL ZERO CROSSING
      ZT2(NPH)=-V2(UNDX)/(V2(UNDX)-V1(UNDX))*SNGL(T2-T1)+SNGL(T2)
C  COMPUTE AREA OF FINAL PORTION OF VOLT. BEFORE Z. CROSS.
      SUM(UNDX)=SUM(UNDX)+V1(UNDX)**2*(ZT2(NPH)-SNGL(T1))
C  INCREMENT CYCLE COUNTER
      CYKNT(NPH)=CYKNT(NPH)+1
C  CHECK FOR FINAL CYCLE OF INTEGRATION RANGE
      IF(CYKNT(NPH).EQ.NCY)GO TO 30
C  CONTINUE SUMMATION WITH NEXT CYCLE
```

```
      SUM(UNDX)=SUM(UNDX)+V2(UNDX)**2*(SNGL(T2)-ZT2(NPH))
C  CHECK FOR ZERO CROSSING OF CURRENT
      IF((V1(NPH).LE.0.).AND.(V2(NPH).GT.0.))GO TO 25
      IF((V1(NPH).GE.0.).AND.(V2(NPH).LT.0.))GO TO 25
C  NO Z. CROSS., EVALUATE FULL TRAPEZOID
      SUM(NPH)=SUM(NPH)+(V1(NPH)**2+V2(NPH)**2)*TDEL
      GO TO 27
C  FIND TIME OF ZERO CROSSING OF CURRENT
25    ZT=-V2(NPH)/(V2(NPH)-V1(NPH))*TDEL+SNGL(T2)
C  EVALUATE SUM AROUND Z. CROSS.
      SUM(NPH)=SUM(NPH)+(V1(NPH)**2*(ZT-SNGL(T1)))
     1+(V2(NPH)**2*(SNGL(T2)-ZT))
C  UPDATE POWER FACTOR SUM
27    PFSUM(NPH)=PFSUM(NPH)+(V1(UNDX)*V1(NPH)*(ZT2(NPH)-SNGL(T1)))
     1+(V2(UNDX)*V2(NPH)*(SNGL(T2)-ZT2(NPH)))
      RETURN
C  FINAL CYCLE OF INTEGRATION RANGE
C
C  CALCULATE PERIOD OF INTEGRATION
30    PERIOD(NPH)=ZT2(NPH)-ZT1(NPH)
C  CALCULATE RMS OF VOLTAGE
      RMS(UNDX)=SQRT(ABS(SUM(UNDX)/2./PERIOD(NPH)))
C  CALCULATE CREST FACTOR
C     CF(NPH)=PEAK(NPH)/RMS(UNDX)
C  BEGIN SUMMATION OF VOLTAGE FOR NEXT CYCLE
      SUM(UNDX)=V2(UNDX)**2*(SNGL(T2)-ZT2(NPH))
C  RESTART PEAK VALUE
      PEAK(NPH)=V2(UNDX)
C  CALCULATE VALUE OF CURRENT AT VOLT. Z. CROSS.
      ZV(NPH)=(V2(NPH)-V1(NPH))*(ZT2(NPH)-SNGL(T1))
     1/SNGL(T2-T1)+V1(NPH)
C  CHECK FOR Z. CROSS. OF CURRENT
      IF((V1(NPH).LE.0.).AND.(ZV(NPH).GT.0.))GO TO 35
      IF((V1(NPH).GE.0.).AND.(ZV(NPH).LT.0.))GO TO 35
```

```
C  NO Z. CROSS., EVALUATE FULL TRAPEZOID
       SUM(NPH)=SUM(NPH)+(U1(NPH)**2+ZU(NPH)**2)*(ZT2(NPH)-SNGL(T1))

       GO TO 40
C  FIND TIME OF ZERO CROSSING
35     ZT=-ZU(NPH)/(ZU(NPH)-U1(NPH))*(ZT2(NPH)-SNGL(T1))+ZT2(NPH)
C  EVALUATE SUM AROUND Z. CROSS.
       SUM(NPH)=SUM(NPH)+(U1(NPH)**2*(ZT-SNGL(T1)))
      1+(ZU(NPH)**2*(ZT2(NPH)-ZT))
C  CALCULATE RMS OF CURRENT
40     RMS(NPH)=SQRT(ABS(SUM(NPH)/2./PERIOD(NPH)))
C  BEGIN SUMMATION OF CURRENT FOR NEXT INTEGRATION PERIOD
C
C  CHECK FOR ZERO CROSSING
       IF((ZU(NPH).LE.0.).AND.(U2(NPH).GT.0.))GO TO 42
       IF((ZU(NPH).GE.0.).AND.(U2(NPH).LT.0.))GO TO 42
C  NO Z. CROSS., EVALUATE FULL TRAPEZOID
       SUM(NPH)=(ZU(NPH)**2+U2(NPH)**2)*(SNGL(T2)-ZT2(NPH))
       GO TO 45
C  FIND TIME OF Z. CROSS.
42     ZT=-U2(NPH)/(U2(NPH)-ZU(NPH))*(SNGL(T2)-ZT2(NPH))+SNGL(T2)
       SUM(NPH)=(ZU(NPH)**2*(ZT-ZT2(NPH)))+(U2(NPH)**2*(SNGL(T2)-ZT)

C  UPDATE BUFFER FULL FLAG
45     BUFULL(NPH)=BUFULL(NPH)+1
C  RESET CYCLE COUNTER
       CYKNT(NPH)=0
C  UPDATE POWER FACTOR SUM
       PFSUM(NPH)=PFSUM(NPH)+(U1(UNDX)*U1(NPH)*(ZT2(NPH)-SNGL(T1)))
C  COMPUTE POWER FACTOR
       PF(NPH)=PFSUM(NPH)/2./PERIOD(NPH)/RMS(UNDX)/RMS(NPH)
C  BEGIN SUMMATION OF POWER FACTOR FOR NEXT CYCLE
       PFSUM(NPH)=U2(UNDX)*U2(NPH)*(SNGL(T2)-ZT2(NPH))
C  COMPUTE PERIOD OF WAVEFORM
       PER(NPH)=DBLE(PERIOD(NPH)/NCY)
```

```
C   SET IDENTIFYING TIME FOR RMS DATA
        CYTM(NPH)=DBLE(ZT1(NPH))
C   EXCHANGE Z. CROSS. TIMES
        ZT1(NPH)=ZT2(NPH)
        RETURN
C   BEGINNING OF INTEGRATION
50      IF(NPH.NE.1)GO TO 55
C   DETERMINE SAMPLE PERIOD
        TDEL=SNGL(T2-T1)
C   FIND TIME OF BEGINNING Z. CROSS.
55      ZT1(NPH)=-V2(VNDX)/(V2(VNDX)-V1(VNDX))*SNGL(T2-T1)+SNGL(T2)
C   INITIALIZE VOLTAGE PEAK VALUE
        PEAK(NPH)=V2(VNDX)
C   INITIALIZE CYCLE COUNTER
        CYKNT(NPH)=0
C   DETERMINE VALUE OF CURRENT AT Z. CROSS.
        ZU(NPH)=(V2(NPH)-V1(NPH))*(ZT1(NPH)-SNGL(T1))/SNGL(T2-T1)+V1(
NPH)
C   START INTEGRATION OF NEW CYCLE
C   SET FLAG
60      PHON(NPH)=1
C   BEGIN SUMMATION OF VOLTAGE
        SUM(VNDX)=V2(VNDX)**2*(SNGL(T2)-ZT1(NPH))
C   CHECK IF CURRENT HAS Z. CROSS.
        IF((ZU(NPH).LE.0.).AND.(V2(NPH).GT.0.))GO TO 70
        IF((ZU(NPH).GE.0.).AND.(V2(NPH).LT.0.))GO TO 70
C   IF NO Z. CROSS., BEGIN SUMMATION OF CURRENT
        SUM(NPH)=(ZU(NPH)**2+V2(NPH)**2)*(SNGL(T2)-ZT1(NPH))
        GO TO 75
C   FIND TIME OF Z. CROSS.
70      ZT=-V2(NPH)/(V2(NPH)-ZU(NPH))*(SNGL(T2)-ZT1(NPH))+SNGL(T2)
C   BEGIN SUMMATION OF CURRENT
        SUM(NPH)=ZU(NPH)**2*(ZT-ZT1(NPH))+V2(NPH)**2*(SNGL(T2)-ZT)
C   BEGIN SUMMATION OF POWER FACTOR
```

```
75    PFSUM(NPH)=(V2(UNDX)*V2(NPH))*(SNGL(T2)-ZT1(NPH))
      RETURN
C  NEG. Z. CROSS. OF VOLTAGE
C  FIND TIME OF Z. CROSS.
80    ZT=-V2(UNDX)/(V2(UNDX)-V1(UNDX))*SNGL(T2-T1)+SNGL(T2)
C  UPDATE VOLT. SUMM.
      SUM(UNDX)=SUM(UNDX)+(V1(UNDX)**2*(ZT-SNGL(T1))
     1+(V2(UNDX)**2*(SNGL(T2)-ZT))
C  CHECK FOR Z. CROSS. OF CURRENT
      IF((V1(NPH).LE.0.).AND.(V2(NPH).GT.0.))GO TO 90
      IF((V1(NPH).GE.0.).AND.(V2(NPH).LT.0.))GO TO 90
C  NOT A Z. CROSS; EVALUATE FULL TRAPE. FOR CURRENT SUM
      SUM(NPH)=SUM(NPH)+(V1(NPH)**2+V2(NPH)**2)*TDEL
C  UPDATE POWER FACTOR SUM
      PFSUM(NPH)=PFSUM(NPH)+(V1(UNDX)*V1(NPH)*(ZT-SNGL(T1))
     1+(V2(UNDX)*V2(NPH)*(SNGL(T2)-ZT))
      RETURN
C  ZERO CROSS. OF CURRENT
C  FIND Z. CROSS. TIME
90    ZT=-V2(NPH)/(V2(NPH)-V1(NPH))*SNGL(T2-T1)+SNGL(T2)
C  UPDATE CURRENT SUMM.
      SUM(NPH)=SUM(NPH)+(V1(NPH)**2*(ZT-SNGL(T1)))+(V2(NPH)**2
     1*(SNGL(T2)-ZT))
C  UPDATE POWER FACTOR SUM
      PFSUM(NPH)=PFSUM(NPH)+(V1(UNDX)*V1(NPH)*(ZT-SNGL(T1))
     1+(V2(UNDX)*V2(NPH)*(SNGL(T2)-ZT))
      RETURN
      END
C
C
      SUBROUTINE DWRITE(N,CURRENT,VOLTAGE,PF,PERIOD,TIME)
C
C  ROUTINE WRITES ONE SET OF ANALYSIS RESULTS TO DISK
C
```

```
      INTEGER CURRENT(1),VOLTAGE(1),PERIOD(1),TIME(1),PF(1)
C  OUTPUT PHASE #
      CALL WRIT29(N,0)
C  OUTPUT RMS CURRENT
      DO 10 I=1,2
10    CALL WRIT29(CURRENT(I),0)
C  OUTPUT RMS VOLTAGE
      DO 20 I=1,2
20    CALL WRIT29(VOLTAGE(I),0)
C  OUTPUT POWER FACTOR
      DO 30 I=1,2
30    CALL WRIT29(PF(I),0)
C  OUTPUT PERIOD
      DO 40 I=1,3
40    CALL WRIT29(PERIOD(I),0)
C  OUTPUT TEST TIME OF CYCLE
      DO 50 I=1,3
50    CALL WRIT29(TIME(I),0)
      RETURN
      END
C
C
      SUBROUTINE DINIT
      CALL WRIT29(0,2)
      RETURN
      END
C
C
      SUBROUTINE DWEOF
      CALL WRIT29(0,1)
      CALL READ29(0,2)
      RETURN
      END
TOTAL RECORDS WRITTEN =    294
```

```
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          SUBROUTINE READA(NADC,V1,V2,T1,T2,EOF)
C
C   ROUTINE MAKES TWO CONSECUTIVE BLOCKS OF "RAW" GENERATOR DATA
C   AVAILABLE TO THE CALLING ROUTINE
C
C   * * * * * * * * * * * * * * * * * * * * *
C   * * * *  CATALOGUED ON UL  10,9,79 * * * * * * * *
C   * * * * * * * * * * * * * * * * * * * * *
C
C   EXTERNAL SUBROUTINES REQUIRED:
C
C      NAME          LOCATION
C   1.GETBLK           UL
C
C
      DIMENSION V1(1),V2(1)
      INTEGER EOF
      DOUBLE PRECISION T1,T2
C   EOF=2 SIGNIFIES FIRST CALL TO THIS ROUITNE
C   TWO FULL BLOCKS OF DATA MUST BE RECEIVED FROM ROUTINE GETBLK
C   LATER CALLS WILL USE LATTER "OLD" SET OF DATA
C   AND ONE "NEW" SET
      IF(EOF.NE.2)GO TO 5
      EOF=0
C   GET FIRST SET OF DATA
      CALL GETBLK(NADC,V1,T1,EOF)
      GO TO 15
C   ON ALL CALLS EXCEPT FIRST, USE SECOND SET OF "OLD" DATA
```

```
C   AS FIRST IN "NEW" PAIR
     5 DO 10 J=1,NADC
    10 V1(J)=V2(J)
       T1=T2
C   GET SECOND SET OF DATA
    15 CALL GETBLK(NADC,V2,T2,EOF)
       RETURN
       END
TOTAL RECORDS WRITTEN =     37
EXIT
$AUR CI 4
$END  LIST
```

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```
      SUBROUTINE GETBLK(NADC,DATA,TIME,EOF)
C
C  ROUTINE GETS A BLOCK OF RAW TEST DATA FROM FILE 30, CONVERTS
C  THE A/D DATA TO EQUIVALENT FLOATING POINT VALUES OF VOLTAGE AND
C  AMPS, AND CONVERTS CLOCK READING TO DOUBLE PRECISION TIME VALUE
C  CORRESPONDING TO NUMBER OF SECONDS AFTER FIRST COMPLETE BLOCK
C  OF DATA.
C  NOTE:  BODY OF ROUTINE IS WRITTEN IN ASSEMBLY LANGUAGE TO SPEED
C  EXECUTION.
C
C  * * * * * * * * * * * * * * * * * * * * * * 
C  * * * * * * CATALOGUED ON UL  10,9,79 * * * * * * *
C  * * * * * * * * * * * * * * * * * * * * * * 
C
C
C  EXTERNAL SUBROUTINES REQUIRED:
C
C    NAME         LOCATION
C
C  1. READ          LB
C  2. READ30        UL
C
C
      DOUBLE PRECISION CLOCK,ZERO,TIMCONST,DBLE
      REAL DATA(1),SCALEF(6),OFFSET(6)
      INTEGER DATADDR,WORD,BUF(120),UFT(10),EOF,NEWCLK(3)
      INTEGER TIME(3),TEMP(4),OLDCLK(3)
      EQUIVALENCE (OFFSET(1),BUF(2)),(SCALEF(1),BUF(14))
```

```
C   SET UP UFT FOR READING CALIBRATION DATA FROM FILE 30
C   NOTE:  ZBFBS = [illegible] CODE FOR 30
        DATA UFT/0,ZBFBS,ZA400,7*0/
C   SET UP CONSTANTS TO BE USED IN ASSEMBLY LANGUAGE CODE
        DATA ZERO,TIMCONST,K12/0.D0,200.D-9,12/
C   NOTE:  TIMCONST = 200 * 10**-9 BECAUSE EACH INCREMENT OF CLOCK
C   CORRESPONDS TO 200 NANOSECONDS (I.E., FREQUENCY = 5MHZ)
C
        DATADDR=0
        IEOF=0
C   CHECK FOR EOF=2 INPUT WHICH IS REQUIRED BEFORE ANY READING CAN
C   TAKE PLACE
        IF(EOF.NE.2)GO TO 10
C   IF EOF=2 (THIS IS FIRST READING OF DATA), EXECUTE FOLLOWING
C   INSTRUCTIONS
C
C   READ CALIBRATION DATA FROM FILE 30
C   NOTE EQUIVALENCES SET UP ABOVE FOR ARRAY BUF
        UFT(4)=23
        CALL READ(BUF,256,UFT)
C   INITIALIZE KEY IN NEWCLK(1) TO INDICATE THIS IS BEGINNING OF
C   READING OF DATA
        NEWCLK(1)=0
C   MUST INTIALIZE READ30 ROUTINE
        CALL READ30(WORD,EOF)
        RETURN
C   FOLLOWING INSTRUCTIONS BUILD BLOCK OF "ADJUSTED" TEST DATA
C
C   GET DATA WORD FROM FILE 30
10      CALL READ30(WORD,EOF)
C   CHECK FOR END OF FILE
        IF(EOF.EQ.1)RETURN
C   FIND BEGINNING OF BLOCK (WORD=0)
        IF(WORD.EQ.0)GO TO 20
```

```
      IF(NEWCLK(1).EQ.0)GO TO 10
C  IF NULL WORD DOES NOT OCCUR EVERY 10TH WORD, NOTIFY USER
      WRITE(2,100)
100   FORMAT(' BLOCK ERROR - SUBROUTINE GETBLK')
      GO TO 10
C  SKIP "0" WORD; GET CLOCK READING
20    CALL READ33(WORD,EOF)
      IF(EOF.EQ.1)RETURN
      INLINE
*  CHECK KEY IN NEWCLK(1) TO SEE IF A PREVIOUS DATA BLOCK EXISTS
        LDM,1  NEWCLK    ;REG1 = NEWCLK(1)
        TRRB,1,1  A1     ;IF PREVIOUS DATA EXISTS, GO TO A1
*  IF NO PREVIOUS BLOCK EXISTS, SET UP STRUCTURE FOR DOUBLE
*  PRECISION FLOATING POINT
*
*  INITIALIZE EXPONENT, #4900 PLACES DECIMAL AFTER END OF LAST BIT
*  (EXPONENT = 126 HEX)
        LDI,1  #4900
        STM,1  NEWCLK    ;NEWCLK(1)=#4900
*  ZERO MIDDLE WORD
        ZRR,1
        STM,1  NEWCLK+1    ;NEWCLK(2)=0
*  PLACE DATA IN LAST WORD
        LDM,1  WORD
        STM,1  NEWCLK+2    ;NEWCLK(3)= CLOCK READING
        BRU A2
*  IF PREVIOUS DATA BLOCK EXISTS, CHECK TO SEE IF CLOCK READING
*  HAS "ROLLED OVER"
*  NOTE:  ROLL OVER OCCURS APPROX. EVERY 13 MSEC.  SEE WRITE-UP
*  FOR CLK CARD IN CUSTOM ELECTRONICS MANUAL FOR DETAILS
A1      LDM,1  WORD    ;REG1 = CLOCK READING
        STM,1  NEWCLK+2    ;NEWCLK(3) = CLOCK READING
*  CHECK TO SEE IF SIGN OF LAST WORD OF PREVIOUS CLOCK READING
*  DIFFERS FORM SIGN OF LAST WORD OF PRESENT CLOCK READING
```

```
        LDM,2  OLDCLK+2    ;REG2 = OLDCLK(3)
        TOR,2,2   ;INVERT
        ORR,2,1   ;COMPARE PREVIOUS TO PRESENT
        TBRB,2,0  A2   ;WERE SIGNS SAME?
*  IF NOT, INCREMENT MIDDLE WORD OF PRESENT READING
        ABMM,15  NEWCLK+1
*  CHECK TO SEE IF THIS CAUSED ENTIRE READING TO ROLL OVER
*  (I.E., SIGN CHANGE FROM PREVIOUS)
        LDM,1  NEWCLK+1    ;REG1 = NEWCLK(2)
        LDM,2  OLDCLK+1    ;REG2 = OLDCLK(2)
        TOR,2,2   ;INVERT REG 2
        ORR,2,1   ;COMPARE TWO READINGS
        TERB,2,0  A2   ;WERE SIGN BITS SAME?
*  IF NOT, INCREMENT EXPONENT OF PRESENT READING
        ABMM,15  NEWCLK
*  FOLLOWING INSTRUCTIONS CONVERT CLOCK READING TO SECONDS
A2      LFM,4  NEWCLK   ;REGS 4,5,6 = CLOCK READING
        FAMD,4  ZERO   ;NORMALIZE
        FMMD,4  TIMCONST   ;CONVERT TO SECONDS
*  STORE REGS 4,5,6,7 IN TEMPORARY LOCATION
        SFM,4  TEMP
*  GET USEFUL INFORMATION (DOUBLE PRECISION FLOATING POINT
*  REPRESENTATION OF TIME) IN REGS 5,6,7
        LFM,5  TEMP
*  STORE TIME READING IN RETURN VARIABLE
        SFMS,5  TIME
*  SAVE PRESENT CLOCK READING TO BE USED FOR CHECKING IF NEXT
*  READING HAS ROLL OVER
        LFM,5  NEWCLK
        SFM,5  OLDCLK
*  FOLLOWING CODE INPUTS 6 DATA WORDS AND ADJUSTS EACH BY
*  SUBTRACTING OFFSET AND MULTIPLYING BY SCALE FACTOR
*
*  INITIALIZE LOOP COUNTER IN REG 1
```

```
      ZRR,1
*  OBTAIN ADDRESS OF DATA (RETURN VARIABLE)
      LDM,2  DATA    ;GET ADDR OF DATA
      STM,2  DATADDR
*  FOLLOWING IS LOOP WHICH INPUTS AND ADJUSTS SIX DATA WORDS
A3    STM,1  TEMP    ;SAVE LOOP COUNTER IN TEMP(1)
*  CALL READ30 WHICH INPUTS A DATA WORD FROM DISK FILE 30
      BLM,8  READ30
      DFC  2,WORD,IEOF    ;PASS PARAMETERS
      LDM,1  TEMP    ;RESTORE LOOP COUNTER
      LDM,3  WORD    ;GET A/D DATA WORD
      TTR,3,3    ;MUST INVERT IT
*  SET UP EXPONENT OF SINGLE PRECISION FLOATING POINT NUMBER.
*  #41C0 REPRESENTS EXPONENT OF 107 HEX WHICH PLACES DECIMAL
*  AFTER FIRST BIT OF BINARY FRACTION (A/D READING IS < 1)
      LDI,2  #41C0
*  CHECK IF DATA WORD IS NEGATIVE
      TERB,3,0  A5    ;IF NEGATIVE, GO TO A5
*  SUBTRACT APPROPRIATE OFFSET VALUE WHICH IS LOCATED BY USING
*  REG 1 AS AN INDEX
A4    FSM,2,1  OFFSET
      FMM,2,1  SCALEF    ;MULTIPLY BY APPROPRIATE SCALE FACTOR
*  STORE EXPONENT IN FIRST WORD OF DATA WHICH IS POINTED TO
*  BY DATADDR
      STMM,2  DATADDR
*  INCREMENT DATADDR TO POINT TO SECOND WORD OF DATA
      ADMM,15  DATADDR
*  STORE BINARY FRACTION IN DATA
      STMM,3  DATADDR
*  INCREMENT DATADDR TO POINT TO FIRST WORD OF NEXT ELEMENT
*  OF DATA ARRAY
      ADMM,15  DATADDR
      AIR,1,14    ;INCREMENT LOOP COUNTER BY 2
      CRMB,1  K12,C+4,A3    ;CHECK FOR END OF LOOP,IF NOT BRANCH B
ACK
```

```
              BRU A6
      *  FOR A NEGATIVE A/D DATA WORD, MUST ADJUST SIGN BIT IN
      *  EXPONENT AND ADJUST DATA WORD
      A5      ZRR,4
              ZRR,5    ;PREPARE REGS 4,5
              TTR,3,3    ;INVERT REG 3,BINARY FRACTION PART OF DATA WORD
              FSR,4,2    ;SUBTRACT 0,BUT ADJUST WORD
              TRR,2,4
              TRR,3,5    ;PLACE BACK IN REGS 2,3
              BRU A4    ;BRANCH BACK TO ADJUSTING ROUTINE
      A6      NOP    ;EXIT ASSEMBLY LANGUAGE CODE
            FINI
      C  SKIP PARITY AND CHECKSUM WORDS
            CALL READ38(WORD,EOF)
            CALL READ38(WORD,EOF)
            RETURN
            END
TOTAL RECORDS WRITTEN =    182
EXIT
$AVR CI 4
$END  LIST
```

```
        PGM READ30
        INT READ30
*       SUBROUTINE READ30(WORD,EOF)
*       THIS ROUTINE READS ONE WORD FROM DEVICE 30 AND RETURNS
*       A VALUE EOF=0 OR IF END OF FILE ENCOUNTERED,EOF=1
*       IF THIS ROUTINE IS CALLED WITH EOF=2,ALL POINTERS WILL BE
*       INITIALIZED,WHICH MUST BE DONE BEFORE ANY READING
*       IS ATTEMPTED
READ30  TRR,7,8                                ;GET CALL LOCATION FOR INDEXING
        LDMX,1,7        2                      ;GET EOF
        CRMB,1          K2,$+6,A14 ;SEE IF =2,GO TO A14 OF NOT
        BRU A14
        ZRR,1
        STM,1           TRKNUM                 ;TRKNUM=0
        ABR,1,15
        STM,1           MAXTRK                 ;MAXTRK=1
        LDI,1           3000
        STM,1           POINT                  ;POINT=3000
        BRU,7           3                      ;RETURN
A14     ZRR,1
        STMX,1,7 2      ;EOF=0
        LDM,1           POINT
        CRMB,1 K2944,A10,$+6
        BRU             A10                    ;IF(POINT.GE.2944)GO TO A10
A12     LDM,2,1         BUFF
        STMX,2,7 1         ;WORD=BUFF(POINT)
        ABMM,15         POINT                  ;POINT=POINT+1
        BRU,7           3                      ;RETURN
```

```
A10   LDM,1            TRKNUM
      CRMB,1 MAXTRK,$+4,A11  ;IF(TRKNUM.LT.MAXTRK)GO TO A11
      LDI,1 1
      STM*,1,7         2                 ;EOF=1
      BRU,7            3                 ;RETURN
A11   LDM,1            TRKNUM
      TRRB,1,1         A13               ;IF(TRKNUM.NE.0)GO TO A13
      LDI,1            23
      STM,1            UFT+3             ;SET UP UFT FOR SECTOR 23
      LDI,2            UFT
      REX,0
      DFC BUFF,2
      LDM,1            BUFF
      STM,1            MAXTRK            ;SAVE TRACK COUNT
      LDM,1            TRKNUM
A13   MPM,1            K24
      STM,1            UFT+3             ;UFT+3=TRKNUM*24
      LDI,2            UFT
      REX,0                              ;CALL READ(BUFF,2944*2,UFT)
      DFC BUFF,2944*2
      ADMM,15          TRKNUM            ;TRKNUM=TRKNUM+1
      ZPR,1
      STM,1            POINT             ;POINT=0
      BRU              A12
BUFF  RES 2944
UFT   DFC 0,030 ,#9400,0,0,0
POINT RES 1
TRKNUM RES 1
MAXTRK RES 1
K2    DFC 2
K2944 DFC 2944
K24   DFC 24
      END
TOTAL RECORDS WRITTEN =     62
```

## Appendix B

## Display Software

```
*D MODCOMP SOURCE EDITOR     DATE  04/29/80  14:16:37        PAGE   1

          PROGRAM DISPLAY
C
C   ROUTINE PRESENTS VARIOUS PLOTS OF GENERATOR TEST DATA.
C   TEST DATA WAS ACQUIRED DURING EXECUTION OF ROUTINE RUNSYS.
C   THIS RAW DATA WAS ANALYZED BY ROUTINE ANALYSIS AND STORED
C   ON DISK FILE 29.
C   THIS ROUTINE READS THE CONDENSED DATA AND DISPLAYS IT TO
C   THE USER VIA A TEKTRONIX TERMINAL.
C   USER SELECTS DISPLAY BY ENTERING OPT COMMANDS.
C   LIST OF OPT COMMANDS AND DEFINITION:
C
C   IS - ISOLATE ON RMS VALUES OF CHOSEN PHASE
C   CY - CYCLES; ACTUAL WAVEFORM
C   RE - FULL REPLOT OF INITIAL PLOT
C   QK - QUICK REPLOT OF INITIAL PLOT
C   FQ - PLOT OF FREQUENCY DEVIATION
C   PR - PRINT RMS VALUES PER CYCLE
C
C
C   FURTHER EXPLANATION OF EACH OPTION IS GIVEN IN TEXT OF
C   SUBROUTINE IMPLEMENTING IT.
C
C   FILE ASSIGNMENTS NEEDED FOR THIS ROUTINE:
C
C   7 = TKI (TEKTRONIX INPUT) - FOR ENTERING OPT COMMANDS
C   8 = TKO (TEKTRONIX OUTPUT) - PLOT LABELS,ERROR MESSAGES,ETC.
C   21 = GP1 - SCRATCH FILE FOR FOUT ROUTINE
C   10 = LST - PRINT TABULAR DATA, CONTROLLED BY LST TASK
```

```
C
C * * * * * * * * * * * * * * * * * * * * *
C * * * * *  CATALOGUED ON LM  4,22,80  * * * * * * *
C * * * * * * * * * * * * * * * * * * * * *
C
C EXTERNAL SUBROUTINES REQUIRED BY MAIN AND SUBROUTINES:
C
C      NAME          LOCATION
C
C 1.  READ29            UL
C 2.  INITT             UL
C 3.  VCURSR            UL
C 4.  DWINDO            UL
C 5.  TWINDO            UL
C 6.  MOVEA             UL
C 7.  DRAWA             UL
C 8.  VLABL             UL
C 9.  FOUT              UL
C 10.  HLABL            UL
C 11.  ICUT             UL
C 12.  GETBLK           UL
C 13.  WINCOT           UL
C 14.  DRWREL           UL
C 15.  MOVABS           UL
C 16.  ANSTR            UL
C 17.  READA            UL
C 18.  FOURPLOT         UL
C 19.  CKPLOT           UL
C
      DIMENSION RMSPK(6),JAD(2),TIME(2),PLOTPK(2),DUMK(6)
      INTEGER CPT,PTCNT,EOF
      DOUBLE PRECISION PERIOD(3),TBEGIN
C SET RMS PEAKS TO VALUE FOR INITIAL PLOT
      DATA RMSPK/3*500.,3*150./
```

```
C  NADC = NUMBER OF A/D CONVERTERS USED IN TEST
C  I.E. NUMBER OF CHANNELS OF DATA
      NADC=6
C  NOTIFY USER THAT DATA IS AVAILABLE FOR DISPLAY
C  ERASE SCREEN
      CALL INITT(960)
      WRITE(8,100)
100   FORMAT(1X,40('*'),/,' *****  TEST DATA AVAILABLE'
     1, ' FOR DISPLAY  *****',/,1X,40('*'),/)
C  ALLOW USER TO SELECT "SPECIAL" OPTIONS
      WRITE(8,150)
150   FORMAT(' **** FOR DATA ACQUISITION RATE INFORMATION'
     1,/,' ENTER ''YE''; OTHERWISE, ENTER ''GO''')
      READ(7,200)IANS
200   FORMAT(A2)
      IF(IANS.EQ.'YE')CALL ACSPEED(NADC)
      WRITE(8,250)
250   FORMAT(' **** FOR SPECIAL PLOT OF DRIVE STAND SPEED DATA'
     1,/,' ENTER ''YE''; OTHERWISE FOR GENERATOR'
     1,/,'  TEST SUMMARY PLOT, ENTER ''GO''')
      READ(7,200)IANS
      IF(IANS.EQ.'YE')CALL DSSPEED(TIME,TBEGIN,NAVE,RMSPK)
C  FIND TIME OF FIRST DATA POINT
      CALL GETBLK(N,N,N,2)
      EOF=0
      CALL GETBLK(NADC,DUM,TBEGIN,EOF)
C  DISPLAY INITIAL PLOT OF 3 PHASE VOLTS AND AMPS
C  SET FLAG TO INDICATE INITIAL PLOT AFTER ANALYSIS
      INIT=1
10    CALL GXPLOT(NADC,TBEGIN,RMSPK,INIT)
C  SET FLAG TO INDICATE VERTICAL PLOT
      IHOR=0
C  SELECT FURTHER PLOT OPTIONS
999   WRITE(8,300)
```

```
300   FORMAT(' ENTER PLOT OPTIONS;'
     1,/,' FOR LIST OF OPTIONS, ENTER ''??''')
      CALL PICKOPT(LINE)
      GO TO (90,1000,2000,4000,5000,6000,7000),LINE
C  PRINT RMS VALUES OF SELECTED PHASE OVER SELECTED TIME
C  RANGE
C  SELECT NULL INPUT (JAD(1)), PHASE TO BE DISPLAYED (JAD(2)),
C  BEGINNING TIME OF DISPLAY (TIME(1)), AND ENDING TIME (TIME(2))
1000  CALL PICKTIME(JAD,TIME,IHOR)
      CALL ISOLATE(NADC,JAD,TIME,RMSPK,TBEGIN)
C  SET FLAG TO INDICATE HORIZONTAL PLOTTING
      IHOR=1
C  SELECT PLOT OPTIONS
      GO TO 999
C  PLOT ACTUAL WAVEFORMS OF SELECTED PHASE
C  SELECT PHASE TO BE DISPLAYED, JAD(1), AND FLAG WHETHER DATA
C  POINTS ARE TO BE HIGHLIGHTED (YES,JAD(2)=1;NO,JAD(2)=0),
C  BEGINNING (TIME(1)) AND ENDING (TIME(2)) PLOT TIMES
2000  CALL PICKTIME(JAD,TIME,IHOR)
      CALL PLOTCY(JAD,NADC,TIME,RMSPK,TBEGIN)
C  SET FLAG TO INDICATE HORIZONTAL PLOTTING
      IHOR=1
C  ASK USER IF HE WANTS FOURIER ANALYSIS
      WRITE(8,2500)
2500  FORMAT(' TO PERFORM FOURIER ANALYSIS,'
     1' ENTER ''YE''; OTHERWISE ENTER, ''GO''')
      READ(7,200)IANS
      IF(IANS.NE.'YE')GO TO 999
C  PICK PHASE AND CYCLE FOR ANALYSIS
      CALL PICKTIME(JAD,TIME,IHOR)
C  PERFORM FOURIER ANALYSIS
      CALL FOURIER(JAD(1),TIME,IANS)
C  DETERMINE IF CKPLOT WAS INVOKED
C  IF NOT, GO TO NEW PLOT IMMEDIATELY
```

```
      IF(IANS.NE.'CK')GO TO 4000
C  IF SO, WAIT FOR USER RESPONSE
      READ(7,200)IANS
C  MUST NOW PRODUCE QUICK PLOT IN ORDER TO CHOOSE NEW OPTION
      GO TO 4000
C  REPLOT QUICK (AVERAGED) PLOT OF 3 PHASE VOLTS AND AMPS.
C  USED MAINLY FOR SELECTING TIME RANGE TO BE USED IN
C  OTHER PLOT OPTIONS
4000  GO TO 10
C  PRODUCE FREQUENCY DEVIATION DISPLAY
C  SELECT PHASE VOLTAGE TO BE DISPLAYED (JAD(1)),NULL
C  INPUT (JAD(2)), BEGINNING TIME OF DISPLAY (TIME(1)),
C  AND ENDING TIME (TIME(2))
5000  CALL PICKTIME(JAD,TIME,IHOR)
C  PLOT FREQUENCY DEVIATION
      CALL FREQDEV(JAD(2),TIME(1),TIME(2),TBEGIN)
C  SET FLAG TO INDICATE HORIZONTAL PLOTTING
      IHOR=1
C  SELECT PLOT OPTIONS
      GO TO 999
C  PRODUCE TABULAR DISPLAY OF TEST DATA
C  SELECT PHASE TO BE DISPLAYED (JAD(1)), NUMBER OF READINGS
C  TO BE AVERAGED BEFORE DISPLAYING (JAD(2)=1,9), BEGINNING
C  TIME OF DISPLAY (TIME(1)), AND ENDING TIME (TIME(2))
6000  CALL PICKTIME(JAD,TIME,IHOR)
C  PRODUCE TABLE
      CALL PRINTVAL(JAD,TIME,TBEGIN)
C  WAIT FOR OPERATOR ACTION
      GO TO 7000
C  PRODUCE TABULAR DISPLAY OF RAW DATA
7000  CALL PICKTIME(JAD,TIME,IHOR)
C  PRODUCE TABLE
      CALL PRINTCY(JAD,NADC,TIME,TBEGIN)
C  WAIT FOR OPERATOR ACTION
```

```
 7500   READ(7,111,END=90)OPT
 111    FORMAT(A2)
 C  GO BACK TO INITIAL PLOT,QUICK
        GO TO 4000
 90     STOP
        END
 C
 C
        SUBROUTINE PICKOPT(LINE)
 C
 C  ROUTINE ENABLES USER TO SELECT FURTHER PLOTS TO BE DISPLAYED.
 C  LINE - OUTPUT VARIABLE; LINE NUMBER IN MAIN ROUTINE
 C  TO BE EXECUTED UPON RETURN
 C
        INTEGER OPT
 C  SELECT PLOT OPTION
 10     READ(7,100,END=90)OPT
 100    FORMAT(A2)
 C  DOES USER WANT TABLE OF AVAILABLE OPTIONS?
        IF(OPT.NE.'??')GO TO 50
        WRITE(6,15)
 15     FORMAT(//,1X,'IS - RMS VOLTAGE AND CURRENT PLOT'
       1,/,1X,'CY - INSTANT. VOLTAGE AND CURRENT PLOT'
       2,/,1X,'RR - RMS DATA TABLE',/,1X,
       3'OK - TEST SUMMARY PLOT OF RMS DATA',/,1X,
       4'FQ - FREQUENCY DEVIATION PLOT',/,1X,
       5'PC - INSTANT. DATA TABLE',/,1X,'00 - TO EXIT DISPLAY'
       6,///,1X,'NOTE:  SOME OPTIONS ARE NOT APPROPRIATE'
       7,/,1X,'IN ALL INSTANCES.  SEE DISPLAY USAGE'
       8,/,1X,'WRITE-UP FOR FURTHER DETAILS.')
 C  GET OPTION
        GO TO 10
 C  SET LINE FOR RETURN
 C  INITIALIZE LINE AT 0, IF UNCHANGED AT END  - ERROR
```

AD-A100 785 AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH SCHOO--ETC F/G 14/2
COMPUTER ANALYSIS OF 400 HZ AIRCRAFT ELECTRICAL GENERATOR TEST --ETC(U)
JUN 80 P G GABERDIEL
UNCLASSIFIED AFIT/GCS/EE/80-1 NL

2 OF 2

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```
50    LINE=0
      IF(OPT.EQ.'IS')LINE=2
      IF(OPT.EQ.'CY')LINE=3
      IF(OPT.EQ.'GK')LINE=4
      IF(OPT.EQ.'FQ')LINE=5
      IF(OPT.EQ.'PR')LINE=6
      IF(OPT.EQ.'PC')LINE=7
      IF(LINE.NE.0)RETURN
C  PRINT ERROR MESSAGE
      WRITE(8,200)
200   FORMAT(' INVALID COMMAND')
      GO TO 10
80    LINE=1
90    RETURN
      END
C
C
      SUBROUTINE PICKTIME(JAD,TIME,OPT)
C
C  ROUTINE ALLOWS USER TO SELECT A BEGINNING AND ENDING TIME
C  FOR USE IN PLOT.  THIS IS DONE BY POSITIONING CURSOR TO
C  SELECTED TIME AND PRESSING A KEYBOARD CHARACTER THEN
C  CARRIAGE RETURN.  THESE CHARACTERS (JAD(1) AND JAD(2))
C  ARE RETURNED TO THE CALLING ROUTINE AS INTEGER VALUES.
C  NOTE:  OPT IS INPUT VARIABLE WHICH SPECIFIES WHETHER
C  IN PRESENT PLOT TIME AXIS IS VERTICAL (OPT=3) OR
C  HORIZONTAL (OPT=1).
C
      DIMENSION JAD(1),TIME(1)
      INTEGER OPT
C  SELECT 2 TIME VALUES AND CHARACTERS
      DO 2 K=1,2
C  ADJUST OPT SO THAT IT CAN BE USED IN COMPUTED GO TO
C  STATEMENT
```

```
1     KOPT=OPT+1
C  GO TO ROUTINE WHICH HANDLES TIME AXIS SPECIFIED BY OPT
15    GO TO(10,20),KOPT
C  ROUTINE WHICH HANDLES VERTICAL TIME AXIS.
C  GET A CHARACTER AND TIME VALUE
C  NOTE:  VAL IS X VALUE OF CURSOR AND IS NOT USED
10    CALL VCURSR(JAD(K),VAL,TIME(K))
      GO TO 30
C  ROUTINE WHICH HANDLES HORIZONTAL TIME AXIS
C  NOTE:  VAL IS Y VALUE OF CURSOR AND IS NOT USED
20    CALL VCURSR(JAD(K),TIME(K),VAL)
C  CONVERT ASCII CHARACTER TO INTEGER VALUE
30    JAD(K)=IAND(ISHFT(JAD(K),-8),Z27F)-Z230
C  CHECK FOR VALID CHARACTER
      IF(JAD(K).LT.0.OR.JAD(K).GT.9)GO TO 15
    2 CONTINUE
      RETURN
      END
C
C
      SUBROUTINE GKPLOT(NADC,TBEGIN,PEAK,INIT)
C
C  ROUTINE PLOTS A SUMMARY OF GENERATOR TEST DATA CONSISTING
C  OF 3 PHASE RMS VOLTAGES AND 3 PHASE RMS CURRENTS.
C  THIS PLOT IS USED IN SELECTING FURTHER PLOT OPTIONS
C  FOLLOWING ANY DISPLAY WHICH DOES NOT HAVE A TIME SCALE
C  (E.G., INITIAL PLOT, TABLES, FOURIER COEFFICIENTS, ETC.)
C  NOTE:  DATA IS AVERAGED SO THAT ONLY 100 POINTS ARE PLOTTED.
C  PLOTS ARE SCALED TO ACCOMODATE MAXIMUM READING.
C  FIRST CALL OF THIS ROUTINE AFTER ANALYSIS OF DATA
C  (INDICATED BY INIT=1) DETERMINES MAXIMUM RMS VALUES FOR
C  EACH PHASE VOLTS AND AMPS (PEAK), A MAXIMUM SCALE FOR
C  VOLTS AND AMPS (SCALE), AND ACTUAL STARTING AND ENDING
C  TIMES OF ANALYZED DATA (ZTIMF AND ZTIML).
```

```
C
      DIMENSION PEAK(1),TEMPK(6),SCALE(2)
      INTEGER EOF
      DOUBLE PRECISION ZTIMF,ZTIML,TBEGIN,TIME,PER
C DETERMINE IF INITIAL CALL
      IF(INIT.NE.1)GO TO 5
C  SET START TIME FOR PLOT EQUAL TO TIME OF FIRST
C  DATA POINT
      ZTIMF=TBEGIN
C  DEFAULT END TIME FOR PLOT
      ZTIML=DBLE(6.)
C  INITIALIZE ARRAY TO DETERMINE MAX. OF EACH SIGNAL
      DO 10 J=1,NADC
10    TEMPK(J)=0.
C  SET INITIAL VALUES FOR SCALES
      SCALE(1)=PEAK(1)
      SCALE(2)=PEAK(4)
C  ERASE SCREEN
5     CALL INITT(960)
C  PRINT LABEL INFORMATION STORED DURING PRE-TEST CALIBRATION
C  OF A/D CONVERTERS
      CALL LABL
C  DETERMINE SIZE OF TIME INCREMENT REQUIRED TO PLOT
C  100 POINTS
      TIMDIV=(SNGL(ZTIML-ZTIMF))/100.
C  SET PHASE NUMBER
      NPH=1
C  REWIND DATA FILE
15    CALL READ25(0,2)
C  INITIALIZE END OF FILE FLAG
      EOF=0
C  INITIALIZE TIME MARKER
      TIMMRK=TIMDIV
C  INITIALIZE POINT COUNTER
```

```
      IPTS=0
C   INITIALIZE RUNNING TOTALS
      VOLTSUM=0.
      AMPSUM=0.
C   COMPUTE FIRST AVERAGE
C
C   GET FIRST DATA SET
20    CALL DREAD(NPH,AMP,VOLT,PF,PER,TIME,EOF)
C   UPDATE PEAK VALUES
      IF(INIT.NE.1)GO TO 25
      IF(AMP.GT.TEMPK(NPH))TEMPK(NPH)=AMP
      IF(VOLT.GT.TEMPK(NPH+3))TEMPK(NPH+3)=VOLT
C   ADD NEW VALUES TO RUNNING TOTALS
25    AMPSUM=AMPSUM+AMP
      VOLTSUM=VOLTSUM+VOLT
C   INCREMENT POINT COUNTER
      IPTS=IPTS+1
C   CHECK IF TIME MARKER EXCEEDED,
C   IF NOT, GET NEXT DATA SET
      IF(SNGL(TIME).LT.TIMMRK)GO TO 20
C   COMPUTE AVERAGE VALUES AND SAVE FOR PLOTTING
      PLOTA=AMPSUM/IPTS
      PLOTV=VOLTSUM/IPTS
C   SAVE TEST TIME FOR PLOTTING
      PLOTTM=SNGL(TIME)
C   INCREMENT TIME MARKER
27    TIMMRK=TIMMRK+TIMDIV
C   COMPUTE SECOND AVERAGED PLOT VALUE
C
C   RESET POINT COUNTER
      IPTS=3
C   RESET TOTALS
      AMPSUM=3.
      VOLTSUM=0.
```

```
C   GET NEXT DATA SET
30     CALL DREAD(NPH,AMP,VOLT,PF,PER,TIME,EOF)
C   IF END OF FILE REACHED, CHANGE PHASE
       IF(EOF.EQ.1)GO TO 40
C   UPDATE PEAK ARRAY
       IF(INIT.NE.1)GO TO 35
       IF(AMP.GT.TEMPK(NPH))TEMPK(NPH)=AMP
       IF(VOLT.GT.TEMPK(NPH+3))TEMPK(NPH+3)=VOLT
C   ADD NEW VALUES TO TOTALS
35     AMPSUM=AMPSUM+AMP
       VOLTSUM=VOLTSUM+VOLT
C   INCREMENT POINT COUNTER
       IPTS=IPTS+1
C   CHECK IF TIME MARKER EXCEEDED
       IF(SNGL(TIME).LT.TIMMRK)GO TO 30
C   COMPUTE AVERAGE VALUES
       AMPSUM=AMPSUM/IPTS
       VOLTSUM=VOLTSUM/IPTS
C   PLOT TWO AVERAGED CURRENT VALUES
C
C   SET VIRTUAL WINDOW
       CALL DWINDO(-SCALE(1),0.,SNGL(ZTIMF),SNGL(ZTIML))
C   COMPUTE VALUE TO BE USED IN SETTING SCREEN WINDOW
       INC=170*(NPH-1)
C   SET SCREEN WINDOW
       CALL TWINDO(10+INC,160+INC,120,760)
C   MOVE TO FIRST POINT
       CALL MOVEA(-PLOTA,PLOTTM)
C   DRAW TO SECOND POINT
       CALL DRAWA(-AMPSUM,SNGL(TIME))
C   SAVE SECOND POINT FOR NEXT PLOT
       PLOTA=AMPSUM
C   PLOT TWO AVERAGED VOLTAGE VALUES
C
```

```
C     SET VIRTUAL WINDOW
         CALL DWINDO(-SCALE(2),0.,SNGL(ZTIMF),SNGL(ZTIML))
C     COMPUTE VALUE TO BE USED IN SETTING SCREEN WINDOW
         INC=170*(NPH+3-1)
C     SET SCREEN WINDOW
         CALL TWINDO(10+INC,160+INC,120,760)
C     MOVE TO FIRST POINT
         CALL MOVEA(-PLOTV,PLOTTM)
C     DRAW TO SECOND POINT
         CALL DRAWA(-VOLTSUM,SNGL(TIME))
C     SAVE SECOND POINT FOR NEXT PLOT
         PLOTV=VOLTSUM
C     SAVE TIME
         PLOTTM=SNGL(TIME)
C     GET NEXT DATA SET
         GO TO 27
C     DRAW CURRENT AXIS
C
C     SET VIRTUAL WINDOW
40       CALL DWINDO(-SCALE(1),0.,SNGL(ZTIMF),SNGL(ZTIML))
C     SET SCREEN WINDOW
         INC=170*(NPH-1)
         CALL TWINDO(10+INC,160+INC,120,760)
         CALL MOVEA(0.,SNGL(ZTIML))
         CALL DASHA(0.,SNGL(ZTIMF),12)
C     DRAW VOLTAGE AXIS
         CALL DWINDO(-SCALE(2),0.,SNGL(ZTIMF),SNGL(ZTIML))
         INC=170*(NPH+3-1)
         CALL TWINDO(10+INC,160+INC,120,760)
         CALL MOVEA(0.,SNGL(ZTIML))
         CALL DASHA(0.,SNGL(ZTIMF),12)
C     CHANGE PHASE NUMBER
         NPH=NPH+1
C     CHECK FOR COMPLETION
```

```
      IF(NPH.LE.3)GO TO 15
C  LABEL EACH PLOT WITH ITS PEAK VALUE
      WRITE(8,1500)(TEMPK(J),J=1,6)
1500  FORMAT(/,1X,6('PEAK=',F5.0,2X))
C  LABEL WITH PHASE INFO
      WRITE(8,1000)
1000  FORMAT(1X,/,2(2X,'PHASE  1',4X,'PHASE  2',4X,
     1'PHASE  3',2X))
      WRITE(8,2000)
2000  FORMAT(1X,3(2X,'CURRENT',3X),3(2X,'VOLTAGE',3X))
C  SAVE FINAL DATA TIME
      IF(INIT.NE.1)GO TO 60
      ZTIML=TIME
C  SET PEAK ARRAY
      DO 250 J=1,NADC
250   PEAK(J)=TEMPK(J)
C  DETERMINE ACTUAL SCALE VALUES
      SCALE(1)=PEAK(1)
      IF(PEAK(2).GT.SCALE(1))SCALE(1)=PEAK(2)
      IF(PEAK(3).GT.SCALE(1))SCALE(1)=PEAK(3)
      SCALE(2)=PEAK(4)
      IF(PEAK(5).GT.SCALE(2))SCALE(2)=PEAK(5)
      IF(PEAK(6).GT.SCALE(2))SCALE(2)=PEAK(6)
C  RESET INITIAL CALL FLAG
      INIT=0
C  WAIT FOR USER RESPONSE
60    READ(7,3000)IANS
3000  FORMAT(A2)
      RETURN
      END
C
C
      SUBROUTINE LABL
      INTEGER UFT(6),LABLE(36)
```

```
C       PROGRAM PUTS TEXT FROM ADDISK PROGRAM ON TOP OF SCREEN
        DATA UFT/2*0,ZA400,3*0/
        UFT(2)=ICAN(30)
        UFT(4)=47
        CALL READ(LABLE,72,UFT,.TRUE.)
        CALL HLABL(0,775,LABLE,72)
        RETURN
        END
C
C
        SUBROUTINE ISOLATE(NADC,JAD,TIME,PEAK,TBEGIN)
C
C     ROUTINE WHICH PLOTS RMS VALUES FOR VOLTAGE AND CURRENT OF
C     PHASE SELECTED IN JAD(1) OVER TIME RANGE TIME(1) TO TIME(2)
C
        DIMENSION JAD(1),TIME(1),PEAK(1)
        INTEGER EOF
        DOUBLE PRECISION ZTIM1,ZTIM2,TBEGIN,PERIOD
C     ERASE SCREEN
        CALL INITT(960)
C     SET PHASE NUMBER
        NPH=JAD(1)
C     INITIALIZE DISC READ
        CALL READES(0,2)
C     INITIALIZE EOF OF FILE FLAG (EOF)
        EOF=0
C     READ FIRST SET OF DATA
1       CALL DREAD(NPH,AMP1,VOLT1,PF,PERIOD,ZTIM1,EOF)
C     CHECK TO SEE IF IN TIME RANGE REQUESTED
        IF(SNGL(ZTIM1).LT.TIME(1))GO TO 1
C     INITIALIZE VARIABLES FOR COMPUTING AVERAGE OF PF,VOLTAGE,
C     AND CURRENT OVER TIME RANGE DISPLAYED
        PFSUM=PF
        VAVE=VOLT1
```

```
      CAVE=AMP1
C  INITIALIZE POINT COUNTER
      NCNT=1
C  READ NEXT SET OF DATA
5     CALL DREAD(NPH,AMP2,VOLT2,PF,PERIOD,ZTIM2,EOF)
C  UPDATE AVERAGE ACCUMULATION VARIABLES
      PFSUM=PFSUM+PF
      VAVE=VAVE+VOLT2
      CAVE=CAVE+AMP2
C  INCREMENT POINT COUNTER
      NCNT=NCNT+1
C  CHECK TO SEE IF EOF ENCOUNTERED
      IF(EOF.EQ.1)GO TO 15
C  SET SCREEN TO PLOT PHASE VOLTAGE
      CALL DWINDO(TIME(1),TIME(2),-.5,PEAK(NPH+3))
      CALL TWINDO(100,900,400,700)
C  MOVE TO PRECEDING POINT AND THEN PLOT CURRENT POINT
      CALL MOVEA(SNGL(ZTIM1),VOLT1)
      CALL DRAWA(SNGL(ZTIM2),VOLT2)
C  SET SCREEN FOR PHASE CURRENT
      CALL DWINDO(TIME(1),TIME(2),-.5,PEAK(NPH))
      CALL TWINDO(100,900,100,400)
C  PLOT CURRENT VALUES
      CALL MOVEA(SNGL(ZTIM1),AMP1)
      CALL DRAWA(SNGL(ZTIM2),AMP2)
C  CHECK TO SEE IF REQUESTED TIME RANGE HAS BEEN EXCEEDED
      IF(SNGL(ZTIM2).GE.TIME(2))GO TO 15
C  INTERCHANGE PREVIOUS AND PRESENT DATA VALUES
      ZTIM1=ZTIM2
      VOLT1=VOLT2
      AMP1=AMP2
C  GET NEXT SET OF DATA
      GO TO 5
C  COMPUTE AVERAGE VALUES FOR PF,VOLTAGE, AND CURRENT
```

```
15    PFAVE=PFSUM/NCNT
      VAVE=VAVE/NCNT
      CAVE=CAVE/NCNT
C  COMPUTE REAL AND REACTIVE POWER VALUES BASED ON AVERAGE
C  VALUES COMPUTED FOR VOLTAGE,CURRENT, AND POWER FACTOR
      REALPWR=(VAVE*CAVE*PFAVE)/1000.
      PWRIMG=VAVE*CAVE
      REACPWR=(SQRT((PWRIMG**2)-((REALPWR*1000.)**2)))/1000.
C  PLOT AXIS
C  SET SCREEN TO LABEL VOLTAGE PLOT
      CALL DWINDO(TIME(1),TIME(2),-.5,PEAK(NPH+3))
      CALL TWINDO(100,980,400,760)
C  DRAW AXES FOR VOLTAGE PLOT
      CALL MOVEA(TIME(1),PEAK(NPH+3))
      CALL DRAWA(TIME(1),0.)
      CALL DRAWA(TIME(2),0.)
C  LABEL VOLTAGE PLOT
      CALL TWINDO(10,1010,400,760)
      CALL VLABL(80,680,'VOLTS',5)
C  LABEL PEAK VOLTAGE VALUE
      CALL FOUT(20,750,PEAK(NPH+3),2)
      CALL HLABL(53,750,'-',1)
C  SET SCREEN TO LABEL CURRENT PLOT
      CALL DWINDO(TIME(1),TIME(2),-.5,PEAK(NPH))
      CALL TWINDO(100,980,100,400)
C  DRAW AXES
      CALL MOVEA(TIME(1),PEAK(NPH))
      CALL DRAWA(TIME(1),0.)
      CALL DRAWA(TIME(2),0.)
C  LABEL CURRENT AXIS
      CALL TWINDO(10,1010,50,400)
      CALL VLABL(80,300,'AMPS',4)
C  LABEL PEAK CURRENT VALUE
      CALL FOUT(20,400,PEAK(NPH),2)
```

```
      CALL HLABL(95,390,'-',1)
C  LABEL TEST TIME
      STTM=(TIME(1)-SNGL(TBEGIN))*1000.
      CALL FOUT(90,55,STTM,2)
      FHTM=(TIME(2)-SNGL(TBEGIN))*1000.
      CALL FOUT(900,55,FHTM,2)
      CALL HLABL(300,55,'MSEC AFTER START OF TEST',24)
C  LABEL PHASE NUMBER
      CALL TWINDO(10,1010,100,760)
      CALL VLABL(20,600,'PHASE',5)
      CALL IOUT(20,400,JADC(1))
C  OUTPUT POWER INFORMATION
      CALL TWINDO(10,1010,10,60)
      CALL MOVABS(15,55)
      WRITE(8,100)REALPWR,REACPWR,PFAVE
100   FORMAT(' REAL PWR = ',F5.2,' KW;  REACTIVE PWR = ',F5.2
     1,' KVAR;  AVE PWR FACTOR = ',F5.2)
C  OUTPUT AVERAGE VOLTAGE AND CURRENT VALUES
      WRITE(8,2000)VAVE,CAVE
2000  FORMAT(' AVE RMS VOLTAGE = ',F9.2,' VOLTS;'
     1 ,' AVE RMS CURRENT = ',F9.2,' AMPS')
      CALL TWINDO(100,900,100,400)
C  WAIT FOR USER RESPONSE
      READ(7,3000)IANS
3000  FORMAT(A2)
      RETURN
      END
C
C
      SUBROUTINE PLOTCY(JJ,NADC,TM,PK,TBEGIN)
C
C
C  ROUTINE WHICH PLOTS ACTUAL WAVEFORM OF PHASE VOLTAGE
C  AND PHASE CURRENT OF THE PHASE SPECIFIED BY JJ(1)
```

```
C   JJ(2) SPECIFIES WHETHER DATA POINTS ARE TO BE HIGHLIGHTED
C   (=1,YES; =0,NO)
C   PLOT IS OVER TIME RANGE BETWEEN TM(1) AND TM(2)
C   PK IS AN ARRAY CONTAINING THE PEAK RMS VALUES OF
C   EACH SIGNAL
C
C
        DIMENSION JJ(1),TM(1),PK(1),DATA(6)
        INTEGER EOF,OPT,VNDX,CNDX
        REAL NOWTM,NOWV,NOWC
        DOUBLE PRECISION TIME,TBEGIN,CYTM,PER
C   ACOSD CONVERTS POWER FACTOR INTO PHASE ANGLE
        ACOSD(X)=ATAN(SQRT(1.-X*X)/X)*180./3.1415926
C   VNDX IS INDEX INTO ARRAYS FOR VOLTAGE VALUES
        VNDX=JJ(1)+3
C   CNDX IS INDEX INTO ARRAYS FOR CURRENT VALUES
        CNDX=JJ(1)
C   COMPUTE ABSOLUTE PEAKS FROM RMS PEAKS
        VPK=PK(VNDX)/.707 + 20.
        CPK=PK(CNDX)/.707 + 50.
C   ERASE SCREEN
9       CALL INITT(960)
C   INITIALIZE ROUTINES WHICH READ FROM DISK
        CALL DINIT
        CALL GETBLK(N,N,N,2)
        CALL READ2S(0,2)
C   INITIALIZE EOF FLAG
        EOF=0
C   READ FIRST BLOCK OF DATA
      1 CALL GETBLK(NADC,DATA,TIME,EOF)
C   CHECK FOR END OF FILE
        IF(EOF.EQ.1)RETURN
C   CONVERT TIME READING TO SINGLE PRECISION AND STORE
C   IN NOWTM
```

```
      NOWTM=SNGL(TIME)
C  CHECK TO SEE IF IN TIME RANGE REQUESTED
      IF(NOWTM.LT.TM(1))GO TO 1
C  WANT TO DETERMINE MAXIMUM VALUE OF DATA PLOTTED
C  FOR USE IN LABELLING PLOTS (VMAX,CMAX)
      VMAX=ABS(DATA(VNDX))
      CMAX=ABS(DATA(CNDX))
C  SAVE PRESENT VOLTAGE,CURRENT,AND TIME READINGS
2     TEMPV=DATA(VNDX)
      TEMPC=DATA(CNDX)
      TEMPT=NOWTM
C  READ NEXT BLOCK OF DATA
      CALL GETBLK(NADC,DATA,TIME,EOF)
C  CHECK FOR EOF
      IF(EOF.EQ.1)RETURN
C  SAVE PRESENT TIME,VOLTAGE, AND CURRENT READINGS
      NOWTM=SNGL(TIME)
      NOWV=DATA(VNDX)
      NOWC=DATA(CNDX)
C  PERFORM CHECKS FOR MAX VALUES
      IF(ABS(NOWV).GT.VMAX)VMAX=ABS(NOWV)
      IF(ABS(NOWC).GT.CMAX)CMAX=ABS(NOWC)
C  SET SCREEN TO PLOT VOLTAGE VALUE
400   CALL DWINDO(TM(1),TM(2),-VPK,VPK)
      CALL TWINDO(120,960,400,700)
C  MOVE TO PRECEEDING POINT THEN PLOT PRESENT POINT
      CALL MOVEA(TEMPT,TEMPV)
C  CHECK IF HIGHLIGHT FLAG IS ON
      IF(JJ(2).EQ.0)GO TO 450
C  DRAW SMALL TRIANGLE AT EACH DATA POINT
      CALL DRWTRI(10)
450   CALL DRAWA(NOWTM,NOWV)
C  SET SCREEN TO PLOT CURRENT VALUE
      CALL DWINDO(TM(1),TM(2),-CPK,CPK)
```

```
      CALL TWINDO(120,960,160,460)
C  PLOT CURRENT VALUE
      CALL MOVEA(TEMPT,TEMPC)
      CALL DRAWA(NOWTM,NOWC)
C  CHECK TO SEE IF TIME RANGE EXCEEDED
      IF(NOWTM.LT.TM(2))GO TO 2
C  INITIALIZE VARIABLES TO COMPUTE AVERAGE OF POWER
C  FACTORS OVER MEANINGFUL TIME RANGE
      PF=0.
      IPTS=0
C  INITIALIZE ROUTINE WHICH READS FROM DISK
      CALL READ2S(0,2)
      EOF=0
C  READ BLOCK OF RMS DATA; ONLY VALUES OF INTEREST
C  ARE POWF (4TH PARAMETER)
10    CALL DREAD(CNDX,A,V,POWF,PER,CYTM,EOF)
C  CHECK TO SEE IF IN TIME RANGE REQUESTED
      IF(SNGL(CYTM).LT.TM(1))GO TO 10
C  SET FLAG TO INDICATE IF NO VALID PHASE ANGLE WAS COMPUTED
      NOPH=1
C  IF NO CURRENT IS PRESENT, SKIP THIS READING
20    IF(A.LT.PK(CNDX)-10.)GO TO 25
C  CLEAR FLAG
      NOPH=0
C  SUM PF VALUES
      PF=PF+POWF
C  UPDATE COUNTER
      IPTS=IPTS+1
C  READ ANOTHER BLOCK OF RMS VALUES
25    CALL DREAD(CNDX,A,V,POWF,PER,CYTM,EOF)
C  CHECK FOR EOF
      IF(EOF.EQ.1)GO TO 250
C  CHECK TO SEE IF TIME RANGE EXCEEDED
      IF(SNGL(CYTM).LE.TM(2))GO TO 20
```

```
C   IF NO VALID PHASE ANGLE WAS COMPUTED, SKIP
250    IF(NOPH.EQ.1)GO TO 26
C   COMPUTE AVERAGE VALUE FOR PHASE ANGLE FROM
C   AVERAGE PF VALUE
       PHANG=ACOSD(PF/IPTS)
C   ADJUST PHANG TO VALUE BETWEEN 0 AND 180
       IF(PHANG.LT.0.)PHANG=PHANG+180.
C   PLOT VOLTAGE AXIS
26     CALL DWINDO(TM(1),TM(2),-VPK,VPK)
       CALL TWINDO(120,960,460,760)
C   DRAW VERTICAL AXIS
       CALL MOVEA(TM(1),VPK)
       CALL DRAWA(TM(1),-VPK)
C   DRAW HORIZONTAL AXIS
       CALL MOVEA(TM(1),0.)
       CALL DRAWA(TM(2),0.)
C   SET LARGER SCREEN LIMITS FOR DRAWING LABELS
       CALL TWINDO(10,1010,460,769)
C   LABEL VERTICAL AXIS
       CALL VLABL(900,630,'VOLTS',5)
C   PRINT REFERENCE VALUES
C   IF ACTUAL MAX. VOLTAGE VALUE WAS GREATER THAN EXPECTED,
C   DON'T PRINT ITS REFERENCE VALUE
       IF(VMAX.GT.VPK)GO TO 30
       VLABLE=VMAX
       GO TO 35
30     VLABLE=VPK
35     CALL WINCOT(TM(1),VLABLE,IX,IY)
       CALL FOUT(20,IY,VLABLE,2)
       CALL HLABL(115,IY-10,'-',1)
       CALL WINCOT(TM(1),-VLABLE,IX,IY)
       CALL FOUT(10,IY,-VLABLE,2)
       CALL HLABL(115,IY-10,'-',1)
       CALL WINCOT(TM(1),0.,IX,IY)
```

```
      CALL FOUT(20,IY,0.,2)
C  IF NO PHASE ANGLE INFO., SKIP
      IF(NOPH.EQ.1)GO TO 36
C  LABEL HORIZ. AXIS WITH AVERAGE PHASE ANGLE
      CALL TWINDO(10,1010,440,760)
      CALL HLABL(350,440,'PHASE ANGLE = ',14)
      CALL FOUT(550,440,PHANG,2)
      CALL HLABL(650,440,'DEGREES',7)
C  PLOT CURRENT AXIS
36    CALL DWINDO(TM(1),TM(2),-CPK,CPK)
      CALL TWINDO(120,960,100,400)
C  DRAW VERTICAL AXIS
      CALL MOVEA(TM(1),CPK)
      CALL DRAWA(TM(1),-CPK)
C  DRAW HORIZONTAL AXIS
      CALL MOVEA(TM(1),0.)
      CALL DRAWA(TM(2),0.)
C  SET LARGER SCREEN LIMITS FOR LABELLING
      CALL TWINDO(10,1010,100,400)
C  LABEL VERTICAL AXIS
      CALL VLABL(900,300,'AMPS',4)
C  PRINT REFERENCE VALUES
C  IF ACTUAL MAX. CURRENT WAS GREATER THAN EXPECTED,DON'T
C  PRINT ITS REFERENCE VALUE
      IF(CMAX.GT.CPK)GO TO 40
      CLABLE=CMAX
      GO TO 45
40    CLABLE=CPK
45    CALL WINCOT(TM(1),CLABLE,IX,IY)
      CALL FOUT(20,IY,CLABLE,2)
      CALL HLABL(115,IY-10,'-',1)
      CALL WINCOT(TM(1),-CLABLE,IX,IY)
      CALL FOUT(10,IY,-CLABLE,2)
      CALL HLABL(115,IY-10,'-',1)
```

```
      CALL WINCOT(TM(1),0.,IX,IY)
      CALL FOUT(20,IY,0.,2)
C  LABEL HORIZ. AXIS WITH TIME INFO
C  STTM IS STARTING TIME OF PLOT
      CALL TWINDO(10,1010,50,400)
      STTM=(TM(1)-SNGL(TBEGIN))*1000.
      CALL FOUT(50,50,STTM,2)
C  FHTM IS FINISHING TIME OF PLOT
      FHTM=(TM(2)-SNGL(TBEGIN))*1000.
      CALL FOUT(900,50,FHTM,2)
      CALL HLABL(350,50,'MSEC AFTER START OF TEST',24)
C  SET SCREEN TO LABEL PHASE INFO
      CALL TWINDO(10,1010,100,800)
      CALL HLABL(450,700,'PHASE',5)
      CALL IOUT(530,700,JJ(1))
C  RESET SCREEN LIMITS SO THAT VCURSR WILL WORK
C  CORRECTLY
      CALL TWINDO(100,900,100,400)
C  WAIT FOR USER RESPONSE
      READ(7,100)IANS
100   FORMAT(A2)
C  IF A TRANSIENT TOO BIG TO BE DISPLAYED OCCURRED, THE USER
C  NOW HAS THE OPPORTUNITY TO DISPLAY IT BY REPLOTTING
C  THIS DISPLAY USING UMAX AND CMAX TO SCALE SCREEN
C  TO SELECT REPLOT, ENTER: RE
C  TO CONTINUE, ENTER: GO
      WRITE(8,150)
150   FORMAT(' FOR REPLOT USING ACTUAL SCALING,'
     1' ENTER ''RE''; OTHERWISE ENTER ''GO''')
      READ(7,100)IANS
      IF(IANS.NE.'RE')RETURN
C  RESET SCALES
      UPK=UMAX
      CPK=CMAX
```

```
C  REPLOT
      GO TO 9
      END
C
C
      SUBROUTINE FOURIER(IPH,TIME,IANS)
C
C  THIS ROUTINE COMPUTES FOURIER COEFFICIENTS FOR ONE CYCLE OF
C  PHASE VOLTAGE SPECIFIED BY IPH.  THE CALCULATIONS ARE PERFORMED
C  OVER THE FIRST FULL CYCLE WHICH OCCURS AFTER TIME(1).  A PLOT
C  OF THE FOURIER COEFFICIENTS VERSUS FREQUENCY IS PRESENTED TO
C  DISPLAY THE RESULTS OF THIS ROUTINE.
C
      DIMENSION CSUM(60),DSUM(60),TIME(1),COEFF(60)
     1,VALU1(6),VALU2(6)
      INTEGER EOF
      DOUBLE PRECISION ZTIM,TIM1,TIM2,TDEL,ZTIM1,PERIOD,PERAVE
     1,ZTIME
      DATA PI/3.1415927/
C
C  ADJUST IPH TO INDEX VOLTAGE DATA OF SELECTED PHASE
      NPH=IPH+3
C  SET NUMBER OF A/D CONVERTERS IN USE
      NADC=6
C  DEFINE CONSTANT TO CONVERT DEGREES TO RADIANS FOR USE WITH
C  SINE AND COSINE FUNCTIONS
      RAD=2.*PI
C  COMPUTE AVERAGE PERIOD OF FIRST FIVE CYCLES OF TEST DATA TO
C  DETERMINE BASE FREQUENCY TO BE USED IN ANALYSIS.
C
C  INITIALIZE DISK READ ROUTINE
      CALL READSS(0,2)
C  INITIALIZE END OF FILE FLAG
      EOF=0
```

```
C  INITIALIZE AVERAGE
       PERAVE=0.
5      CALL DREAD(IPH,AMP,VOLT,PF,PERIOD,ZTIME,EOF)
       IF(EOF.EQ.1)GO TO 15
       IF(SNGL(ZTIME).LT.TIME(1))GO TO 5
C  ACCUMULATE VALUES FOR PERIOD
       DO 10 J=1,5
       CALL DREAD(IPH,AMP,VOLT,PF,PERIOD,ZTIME,EOF)
       IF(EOF.EQ.1)GO TO 15
10     PERAVE=PERAVE+PERIOD
C  CALCULATE AVERAGE PERIOD
       PERAVE=PERAVE/5
C  CALCULATE BASE FREQUENCY BASED ON AVERAGE PERIOD
       FREQ=1./SNGL(PERAVE)
C  SET NUMBER OF HARMONICS FOR WHICH FOURIER COEFFICIENTS ARE
C  TO COMPUTED
       WRITE(8,1000)
1000   FORMAT(' ENTER NUMBER OF HARMONICS TO BE COMPUTED,I2')
       READ(7,2000)NHAR
2000   FORMAT(I2)
C  SELECT NUMBER OF CYCLES OVER WHICH TO DETERMINE FOURIER
C  COEFFICIENTS
       WRITE(8,3000)
3000   FORMAT(' ENTER NUMBER OF CYCLES OVER WHICH HARMONIC',1X
      1,/,' ANALYSIS WILL BE PERFORMED,I2')
       READ(7,4000)NAVG
4000   FORMAT(I2)
C  INITIALIZE ROUTINES WHICH READ RAW TEST DATA FROM DISK
       CALL DINIT
       CALL GETBLK(N,N,N,2)
C  SET EOF FLAG TO CAUSE READA ROUTINE TO BEGIN READING OF DATA
       EOF=2
       CALL READA(NADC,VALU1,VALU2,TIM1,TIM2,EOF)
C  CHECK FOR END OF FILE
```

```
      IF(EOF.NE.1)GO TO 20
C  NOTIFY USER THAT END OF FILE OCCURRED AND RETURN TO
C  CALLING ROUTINE
15    WRITE(8,100)
100   FORMAT(' EOF ENCOUNTERED IN FOURIER')
      RETURN
C  CHECK IF IN TIME RANGE REQUESTED
20    IF(SNGL(TIM1).GE.TIME(1))GO TO 30
C  GET NEXT SET OF VALUES
25    CALL READA(NADC,VALU1,VALU2,TIM1,TIM2,EOF)
      IF(EOF.EQ.1)GO TO 15
      GO TO 20
C  CHECK FOR POSITIVE ZERO CROSSING OF PHASE VOLTAGE SELECTED
30    IF((VALU1(NPH).LE.0.).AND.(VALU2(NPH).GT.0.))GO TO 35
C  IF NOT, GET NEXT SET OF VALUES
      CALL READA(NADC,VALU1,VALU2,TIM1,TIM2,EOF)
      IF(EOF.EQ.1)GO TO 15
      GO TO 30
C  INTERPOLATE TO FIND TIME OF ACTUAL ZERO CROSSING
C  NOTE:  THIS TIME WILL BE SUBTRACTED FROM ALL TIME VALUES
C  USED IN SINE AND COSINE FUNCTIONS DURING CALCULATION OF
C  FOURIER COEFFICIENTS.  I.E., ZTIM1 IS TAKEN TO BE THE
C  POINT WHERE TIME=0.
35    ZTIM1=-VALU2(NPH)/(VALU2(NPH)-VALU1(NPH))*(TIM2-TIM1)+TIM2
C
C  COMPUTE POINT-BY-POINT NUMERICAL INTEGRATION OF TEST DATA
C  MULTIPLIED TIMES SINE AND COSINE COMPONENTS OF FREQUENCIES
C  CORRESPONDING TO MULTIPLES OF BASE FREQUENCY.
C
C  INTEGRATION IS PERFORMED USING A TRAPEZOIDAL TYPE COMPUTATION
C
C  DETERMINE WIDTH OF FIRST TRAPEZOID
      TDEL=TIM2-ZTIM1
C  INITIALIZE CYCLE COUNTER
```

```
      NCNT=0
C  INITIALIZE D.C. CONTENT VALUE
      DCONT=0.
C  INITIALIZE VALUES OF VARIABLES WHICH WILL ACCUMULATE
C  INTEGRATION DATA
      DO 36 N=1,NHAR
      CSUM(N)=0.
36    DSUM(N)=0.
C  UPDATE D.C. CONTENT VALUE
37    DCONT=DCONT+VALU2(NPH)*SNGL(TDEL)
      DO 40 N=1,NHAR
C  CSUM IS ACCUMULATION ARRAY FOR COSINE COEFFICIENTS
      CSUM(N)=VALU2(NPH)*COS(N*FREQ*RAD*SNGL(TIM2-ZTIM1))
     1*SNGL(TDEL)
C  DSUM IS ACCUMULATION ARRAY FOR SINE COEFFICIENTS
40    DSUM(N)=VALU2(NPH)*SIN(N*FREQ*RAD*SNGL(TIM2-ZTIM1))
     1*SNGL(TDEL)
C  GET NEXT SET OF VALUES
45    CALL READA(NADC,VALU1,VALU2,TIM1,TIM2,EOF)
      IF(EOF.EQ.1)GO TO 15
C  CHECK FOR POSITIVE ZERO CROSSING, WHICH SIGNALS COMPLETE CYCLE
      IF((VALU1(NPH).LE.0.).AND.(VALU2(NPH).GT.0.))GO TO 65
C  CHECK FOR NEGATIVE ZERO CROSSING
C  NOTE:  TWO TRAPEZOIDS, ONE FOR EACH SIDE OF ZERO CROSSING, MUST
C  BE COMPUTED AT NEGATIVE ZERO CROSSING
      IF((VALU1(NPH).GE.0.).AND.(VALU2(NPH).LT.0.))GO TO 55
C  DETERMINE WIDTH OF TRAPEZOID
      TDEL=TIM2-TIM1
C  ACCUMULATE INTEGRATION VALUES
      DCONT=DCONT+(VALU1(NPH)+VALU2(NPH))*SNGL(TDEL)
      DO 50 N=1,NHAR
      CSUM(N)=CSUM(N)+(VALU1(NPH)*COS(N*FREQ*RAD*SNGL(TIM1-ZTIM1))
     1+VALU2(NPH)*COS(N*FREQ*RAD*SNGL(TIM2-ZTIM1)))*SNGL(TDEL)
50    DSUM(N)=DSUM(N)+(VALU1(NPH)*SIN(N*FREQ*RAD*SNGL(TIM1-ZTIM1))
```

```
      1+VALU2(NPH)*SIN(N*FREQ*RAD*SNGL(TIM2-ZTIM1)))*SNGL(TDEL)
C  GET NEXT SET OF VALUES
       GO TO 45
C  INTERPOLATE TO DETERMINE TIME OF NEGATIVE ZERO CROSSING
55     ZTIM=-VALU2(NPH)/(VALU2(NPH)-VALU1(NPH))*(TIM2-TIM1)+TIM2
C  CALCULATE AREA OF TRAPEZOID JUST BEFORE NEGATIVE ZERO CROSSING
       DCONT=DCONT+VALU1(NPH)*SNGL(ZTIM-TIM1)
      1+VALU2(NPH)*SNGL(TIM2-ZTIM)
       DO 60 N=1,NHAR
       CSUM(N)=CSUM(N)+VALU1(NPH)*COS(N*FREQ*RAD*SNGL(TIM1-ZTIM1))
      1*SNGL(ZTIM-TIM1)
       DSUM(N)=DSUM(N)+VALU1(NPH)*SIN(N*FREQ*RAD*SNGL(TIM1-ZTIM1))
      1*SNGL(ZTIM-TIM1)
C  CALCULATE AREA JUST AFTER ZERO CROSSING
       CSUM(N)=CSUM(N)+VALU2(NPH)*COS(N*FREQ*RAD*SNGL(TIM2-ZTIM1))
      1*SNGL(TIM2-ZTIM)
60     DSUM(N)=DSUM(N)+VALU2(NPH)*SIN(N*FREQ*RAD*SNGL(TIM2-ZTIM1))
      1*SNGL(TIM2-ZTIM)
C  GET NEXT SET OF VALUES
       GO TO 45
C  INTERPOLATE TO DETERMINE TIME OF FINAL POSITIVE ZERO CROSSING
65     ZTIM=-VALU2(NPH)/(VALU2(NPH)-VALU1(NPH))*(TIM2-TIM1)+TIM2
C  CALCULATE AREA OF FINAL TRAPEZOID
       DCONT=DCONT+VALU1(NPH)*SNGL(ZTIM-TIM1)
       DO 70 N=1,NHAR
       CSUM(N)=CSUM(N)+VALU1(NPH)*COS(N*FREQ*RAD*SNGL(TIM1-ZTIM1))
      1*SNGL(ZTIM-TIM1)
70     DSUM(N)=DSUM(N)+VALU1(NPH)*SIN(N*FREQ*RAD*SNGL(TIM1-ZTIM1))
      1*SNGL(ZTIM-TIM1)
C  INCREMENT CYCLE COUNTER
       NCNT=NCNT+1
C  INTERCHANGE ZERO CROSSING TIMES
       ZTIM1=ZTIM
C  CHECK IF CORRECT NUMBER OF CYCLES HAVE BEEN PROCESSED
```

```
      IF(NCNT.LT.NAVG+1)GO TO 37
C  PERFORM CALCULATION TO COMPLETE INTEGRATION
      DCONT=(DCONT/2.)/(SNGL(PERIOD)*NAVG)
      DO 75 N=1,NHAR
      CSUM(N)=(CSUM(N)/2.)/(SNGL(PERAVE)/2.)
75    DSUM(N)=(DSUM(N)/2.)/(SNGL(PERAVE)/2.)
C  CALCULATE MAGNITUDE VALUE FOR COEFFICIENT OF EACH HARMONIC
C  AND DETERMINE MAXIMUM (IGNORING BASE FREQUENCY) FOR USE IN
C  PLOTTING
      COMAX=0.
      DO 80 N=1,NHAR
      COEFF(N)=SQRT(CSUM(N)**2+DSUM(N)**2)
      IF(COEFF(N).GT.COMAX.AND.N.NE.1)COMAX=COEFF(N)
80    CONTINUE
C  CALL ROUTINE WHICH PRODUCES A PLOT OF MAGNITUDES OF FOURIER
C  COEFFICIENTS VERSUS FREQUENCY
      CALL FOURPLOT(COEFF,NHAR,IPH,COMAX,FREQ,DCONT)
      READ(7,200)IANS
200   FORMAT(A2)
      WRITE(8,300)
300   FORMAT(' FOR PLOT OF WAVEFORM REPRESENTED BY FOURIER COEFFICI
ENTS'
     1,/,' ENTER "CK"; OTHERWISE ENTER "GO"')
      READ(7,200)IANS
      IF(IANS.NE.'CK')GO TO 99
      CALL CKPLOT(CSUM,DSUM,NHAR,FREQ)
99    RETURN
      END
C
C
      SUBROUTINE FOURPLOT(COEFF,NHAR,IPH,COMAX,FREQ,DCONT)
C
C  ROUTINE WHICH PRODUCES A DISPLAY OF THE MAGNITUDE OF FOURIER
C  COEFFICIENTS (CALCULATED BY THE ROUTINE FOURIER) VERSUS THE
```

```
C  CORRESPONDING INTEGRAL HARMONIC OF THE BASE FREQUENCY.
C
      DIMENSION COEFF(1)
C  COMPUTE TOTAL HARMONIC DISTORTION
C
C  INITIALIZE RESULT
      THD=0.
C  ACCUMULATE CONTRIBUTIONS OF ALL HARMONICS EXCEPT BASE FREQ.
      DO 5 N=2,NHAR
5     THD=THD+COEFF(N)**2
C  COMPLETE CALCULATION
      THD=(SQRT(THD)/2.)/(COEFF(1)/SQRT(2.))
C  ERASE SCREEN
      CALL INITT(960)
C  OUTPUT LABELS
      WRITE(8,100)IPH
100   FORMAT(///,39X,'FOURIER COEFFICIENTS',/,39X,'OF',/,33X,
     1'PHASE ',I1,' VOLTAGE')
      WRITE(8,200)FREQ,COEFF(1)
200   FORMAT(24(/),5X,'NOTE: BASE FREQUENCY IS ',F7.2,' HZ',/,11X,
     1'MAGNITUDE OF COEFFICIENT = ',F10.4)
      WRITE(8,300)THD
300   FORMAT(11X,'TOTAL HARMONIC DISTORTION = ',F10.4)
C  CONVERT D.C. CONTENT TO MILLIVOLTS
      DCONT=DCONT*1000.
      WRITE(8,400)DCONT
400   FORMAT(11X,'DC CONTENT = ',F10.4,' MV')
C  SET VIRTUAL WINDOW FOR PLOT
      CALL DWINDO(0.,FLOAT(NHAR),0.,COMAX)
C  SET SCREEN SIZE
      CALL TWINDO(200,900,200,600)
C  PLOT MAGNITUDES OF HARMONICS VERSUS HARMONIC NUMBER
      DO 10 N=2,NHAR
      CALL MOVEA(FLOAT(N),0.)
```

```
10     CALL DRAWA(FLOAT(N),COEFF(N))
C  DRAW HORIZ. AXIS
       CALL MOVEA(FLOAT(NHAR+1),0.)
       CALL DRAWA(0.,0.)
C  DRAW VERT. AXIS
       CALL DRAWA(0.,COMAX)
C  LABEL MAGNITUDES OF COEFFICIENTS
       CDEL=COMAX/10.
       CLABEL=COMAX
       IPOS=900
       CALL TWINDO(100,900,200,600)
       DO 20 N=1,10
       CALL FOUT(90,IPOS,CLABEL,4)
       IPOS=IPOS-40
20     CLABEL=CLABEL-CDEL
C  DRAW "HASH" MARKS
       CALL TWINDO(195,900,200,600)
       CLABEL=COMAX
       DO 30 N=1,10
       CALL MOVEA(0.,CLABEL)
       CALL DRWREL(10,0)
30     CLABEL=CLABEL-CDEL
C  LABEL HARMONIC NUMBER
       CALL TWINDO(200,900,180,600)
       DO 40 N=2,NHAR
       CALL MOVEA(FLOAT(N),0.)
40     CALL IOUT(-1,-1,N)
C  LABEL VERT. AXIS
       CALL TWINDO(10,900,200,600)
       CALL VLABL(10,900,'MAGNITUDE',9)
C  LABEL HORIZ. AXIS
       CALL TWINDO(200,900,150,600)
       CALL HLABL(300,150,'HARMONIC OF BASE FREQUENCY',26)
       RETURN
```

```
      END
C
C
      SUBROUTINE CKPLOT(CSUM,DSUM,NHAR,FREQ)
C
C  ROUTINE PRODUCES A DISPLAY WAVEFORM REPRESENTED BY FOURIER
C  COEFFICIENTS CALCULATED BY ROUTINE FOURIER.
C
      DIMENSION CSUM(1),DSUM(1)
C  SET RADIAN CONVERSION FACTOR
      RAD=2.*3.1415927
C  ERASE SCREEN
      CALL INITT(960)
C  SET VIRTUAL WINDOW FOR PLOTTING
      CALL DWINDO(-0.00001,0.00251,-200.,200.)
C  SET SCREEN SIZE
      CALL TWINDO(100,900,100,700)
C  INITIALIZE TIME VALUE
      TIME=0.
C  SET TIME STEP SIZE (NUMBER OF POINTS PLOTTED)
      TDEL=0.00250/22.
C  INITIALIZE PLOT VALUE
      VALUE=0.
C  COMPUTE VALUE AT FIRST TIME INCREMENT
      DO 10 N=1,NHAR
10    VALUE=VALUE+CSUM(N)*COS(N*FREQ*RAD*TIME)
     1+DSUM(N)*SIN(N*FREQ*RAD*TIME)
C  MOVE TO FIRST VALUE ON PLOT
      CALL MOVEA(TIME,VALUE)
C  INCREMENT TIME
15    TIME=TIME+TDEL
C  CHECK FOR COMPLETTION
      IF(TIME.GT.0.00250)GO TO 30
C  RESET VALUE
```

```
      VALUE=0.
C  COMPUTE NEXT VALUE
      DO 20 N=1,NHAR
20    VALUE=VALUE+CSUM(N)*COS(N*FREQ*RAD*TIME)
     1+DSUM(N)*SIN(N*FREQ*RAD*TIME)
C  PLOT VALUE
      CALL DRAWA(TIME,VALUE)
C  COMPUTE NEXT VALUE
      GO TO 15
C  DRAW TIME AXIS
30    CALL MOVEA(0.00250,0.)
      CALL DRAWA(0.,0.)
      RETURN
      END
C
C
      SUBROUTINE FREQDEV(IPH,TIMF,TIML,TBEGIN)
C
C  ROUTINE PRODUCES A PLOT OF RMS VOLTAGE DEVIATION ABOUT
C  100 VRMS OF PHASE SELECTED (IPH) AND A PLOT OF
C  FREQUENCY DEVIATION ABOUT 400 HZ OF
C  PHASE USED AS KEY (PRESENTLY PHASE 2)
C  PLOT IS OVER TIME RANGE TIMF TO TIML
C
      INTEGER EOF,MES1(9),MES2(12)
      DOUBLE PRECISION Z,TBEGIN,PERIOD
      DATA MES1/2HFR,2HEQ,2HUE,2HNC,2HY ,2HVS,2H T,2HIM,2HE /
      DATA MES2/2HPH,2HAS,2HE ,2H  ,2H V,2HOL,2HTA,2HGE,2H V,2HS ,
     12HTI,2HME/
C  SET INITIAL LIMITS FOR PLOTTING VOLTAGE DEVIATION
      VMAX=131.
      VMIN=69.
C  INITIALIZE ROUTINE WHICH READS FROM DISK (REWIND)
10    CALL READ2S(0,2)
```

```
C   RESET END OF FILE FLAG
        EOF=0
C   ERASE SCREEN
        CALL INITT(960)
C   SET SCREEN SIZE TO PLOT FREQUENCY DEVIATION
        CALL DWINDO(TIMF,TIML,359.,441.)
        CALL TWINDO(100,900,100,320)
C   LABEL FREQUENCY AXIS
        DO 20 I=360,440,20
        CALL MOVEA(TIMF,FLOAT(I))
 20     CALL IOUT(-1,-1,I)
        CALL TWINDO(140,900,100,300)
        DO 30 I=360,440,20
        CALL MOVEA(TIMF,FLOAT(I))
 30     CALL DRWREL(10,0)
C   N= NUMBER OF A/D C'S IN USE
        N=6
C   GET FIRST BLOCK OF DATA
 40     CALL DREAD(IPH,A,U,PF,PERIOD,Z,EOF)
C   CHECK FOR EOF
        IF(EOF.EQ.1)GO TO 60
C   CHECK IF IN TIME RANGE REQUESTED
        IF(SNGL(Z).LT.TIMF)GO TO 40
C   CONVERT PERIOD TO FREQUENCY
        FREQ=1./SNGL(PERIOD)
C   MOVE TO STARTING TIME AND FREQUENCY VALUE
        CALL MOVEA(SNGL(Z),FREQ)
C   GET ANOTHER BLOCK OF DATA
 50     CALL DREAD(IPH,A,U,PF,PERIOD,Z,EOF)
C   CHECK FOR EOF OR TIME RANGE EXCEEDED
        IF(EOF.EQ.1.OR.SNGL(Z).GT.TIML)GO TO 60
C   CONVERT PERIOD TO FREQUENCY
        FREQ=1./SNGL(PERIOD)
C   DRAW TO NEW TIME AND FREQUENCY VALUE
```

```
      CALL DRAWA(SNGL(Z),FREQ)
C  GET NEXT BLOCK OF DATA
      GO TO 50
C  PLOT REFERENCE FREQUENCY
60    CALL MOVEA(TIMF,400.)
      CALL DASHA(TIML,400.,12)
C  END OF TIME RANGE REQUESTED
C  SET SCREEN TO LABEL FREQUENCY PLOT
      CALL TWINDO(110,900,60,300)
C  OUTPUT MESSAGE IDENTIFYING FREQUENCY DEVIATION PLOT
      CALL MOVABS(200,60)
      CALL ANSTR(9,MES1)
C  SET SCREEN FOR VOLTAGE DEVIATION PLOT
      CALL DWINDO(TIMF,TIML,VMIN,VMAX)
      CALL TWINDO(100,900,400,700)
C  LABEL VOLTAGE AXIS
      IST=VMIN+1.
      IEND=VMAX-1.
      DO 70 I=IST,IEND,10
      CALL MOVEA(TIMF,FLOAT(I))
70    CALL ICUR(-1,-1,I)
      CALL TWINDO(140,900,400,700)
      DO 80 I=IST,IEND,10
      CALL MOVEA(TIMF,FLOAT(I))
80    CALL DRWREL(10,0)
C  REWIND DATA FILE
      CALL READ2S(6,2)
C  GET FIRST BLOCK OF DATA
90    CALL DREAD(IFH,A,V,PF,PERIOD,Z,EOF)
C  CHECK FOR EOF
      IF(EOF.EQ.1)GO TO 110
C  CHECK IF IN TIME RANGE REQUESTED
      IF(SNGL(Z).LT.TIMF)GO TO 90
C  MOVE TO STARTING TIME AND VOLTAGE VALUE
```

```
      CALL MOVEA(SNGL(Z),V)
C  GET ANOTHER BLOCK OF DATA
100   CALL DREAD(IPH,A,V,PF,PERIOD,Z,EOF)
C  CHECK FOR EOF OR TIME RANGE EXCEEDED
      IF(EOF.EQ.1.OR.SNGL(Z).GT.TIML)GO TO 110
C  DRAW TO TIME AND VOLTAGE VALUE
      CALL DRAWA(SNGL(Z),V)
C  GET NEXT BLOCK OF DATA
      GO TO 100
C  PLOT REFERENCE VOLTAGE
110   CALL MOVEA(TIMF,115.)
      CALL DASHA(TIML,115.,12)
C  SET SCREEN TO LABEL PHASE INFORMATION
      CALL TWINDO(110,500,300,400)
      CALL MOVABS(200,300)
C  DETERMINE WHICH PHASE VOLTAGE WAS PLOTTED
      GO TO(120,130,140),IPH
120   MES2(4)='1 '
      GO TO 150
130   MES2(4)='2 '
      GO TO 150
140   MES2(4)='3 '
150   CALL ANSTR(12,MES2)
      CALL TWINDO(10,1010,50,760)
      PTIMF=(TIMF-SNGL(TBEGIN))*1000.
      CALL FOUT(110,50,PTIMF,2)
      CALL HLABL(370,50,'MSEC',4)
      PTIML=(TIML-SNGL(TBEGIN))*1000.
      CALL FOUT(900,50,PTIML,2)
C  WAIT FOR USER RESPONSE
      READ(7,1000)IANS
1000  FORMAT(A2)
C  IF VOLTAGE DEVIATION PEAK, WAS "OFF SCALE" , USER
C  CAN ENTER 'RE' TO GET PLOT WITH EXPANDED SCALE
```

```
      WRITE(8,2000)
2000  FORMAT(' FOR REPLOT WITH EXPANDED VOLTAGE SCALE,'
     1' ENTER ''RE''; OTHERWISE ENTER ''GO''')
      READ(7,1000)IANS
      IF(IANS.NE.'RE')GO TO 160
C  CHANGE VOLTAGE SCALES
      VMAX=VMAX+10.
      VMIN=VMIN-10.
C  REPLOT
      GO TO 10
C  CHANGE SCREEN WINDOW BACK SO THAT PICKTIME WILL WORK
160   CALL TWINDO(140,980,10,1010)
      RETURN
      END
C
C
      SUBROUTINE PRINTVAL(JAD,TIME,TBEGIN)
C
C  ROUTINE PRODUCES TABULAR DISPLAY OF TEST DATA
C  JAD(1) SELECTS PHASE TO BE DISPLAYED
C  JAD(2) SELECTS NUMBER OF READINGS TO BE AVERAGED BEFORE
C  DISPLAYING (RANGE OF 1 TO 9)
C  TABLE SPANS TIME RANGE TIME(1) TO TIME(2)
C
      DIMENSION TIME(1),JAD(1)
      INTEGER EOF
      DOUBLE PRECISION ZTM,TBEGIN,PERIOD
      NADC=6
      INLINE
        LDI,2  UFT
        REX,07
        BRU OUT
UFT   DFC  0,010,#A000,0,0,0
OUT   NOP
```

```
      FINI
      CALL INITT(960)
      WRITE(10,100)JAD(1),JAD(2)
100   FORMAT(34X,'PHASE  ',I1,//,14X,'EACH ENTRY REPRESENTS'
     1,1X,'AN AVERAGE OF ',I2,' READINGS',///,11X,
     1'RMS VOLTAGE   RMS CURRENT   FREQUENCY',5X,'PF',
     15X,'TIME',/,14X,'(VOLTS)',7X,'(AMPS)',8X,'(HZ)',
     114X,'(SEC)',///)
      CALL READ29(0,2)
1     VSUM=0.
      CSUM=0.
      FSUM=0.
      PFSUM=0.
      JJ=JAD(2)
      DO 10 J=1,JJ
      EOF=0
2     CALL DREAD(JAD(1),AMP,VOLT,PF,PERIOD,ZTM,EOF)
      IF(EOF.EQ.1)GO TO 50
      IF(SNEL(ZTM).LT.TIME(1))GO TO 2
      IF(SNEL(ZTM).GT.TIME(2))GO TO 60
      VSUM=VSUM+VOLT
      CSUM=CSUM+AMP
      FSUM=FSUM+1./SNEL(PERIOD)
10    PFSUM=PFSUM+PF
      VOLTS=VSUM/JAD(2)
      AMPS=CSUM/JAD(2)
      FREQ=FSUM/JAD(2)
      POWF=PFSUM/JAD(2)
      RELTIM=SNEL(ZTM-TBEGIN)
      WRITE(10,200)VOLTS,AMPS,FREQ,POWF,RELTIM
200   FORMAT(14X,F6.1,8X,F6.1,7X,F6.1,5X,F5.3,3X,F9.6)
      GO TO 1
50    WRITE(10,300)
300   FORMAT(' EOF ENCOUNTERED')
```

```
      60 RETURN
         END
C
C
         SUBROUTINE PRINTCY(JJ,NADC,TM,TBEGIN)
C
C     ROUTINE PRODUCES A TABULAR DISPLAY OF RAW TEST DATA
C     JJ(1) SELECTS PHASE TO BE DISPLAYED
C     TABLE SPANS FROM TM(1) TO TM(2)
C
C
         DIMENSION JJ(1),TM(1),DATA(20)
         INTEGER EOF
         REAL MONTH
         DOUBLE PRECISION TIME,TBEGIN
C     VNDX IS INDEX INTO DATA ARRAY FOR VOLTAGE VALUES
         VNDX=JJ(1)*NADC-3
C     CNDX IS INDEX FOR CURRENT VALUES
         CNDX=JJ(1)*NADC-6
C     INITIALIZE ROUTINES WHICH READ FROM DISK
         CALL DINIT
         CALL GETCLK(N,N,N,2)
C     INITIALIZE END OF FILE FLAG
         EOF=0
C     ADVANCE FILE 10 (RESETS LST LINE COUNTER)
         INLINE
           LDI,2  UFT
           REX,07
           BRU  OUT
UFT        DFC  0,010,#A000,0,0,0
OUT        NOP
         FINI
         CALL WAIT(2,2,M)
         WRITE(10,100)JJ(1)
```

```
100   FORMAT(34X,'PHASE  ',I1,///,11X,'VOLTAGE',7X,'CURRENT'
     1,7X,'TIME',///)
C  READ FIRST BLOCK OF DATA
1     CALL GETBLK(NADC,DATA,TIME,EOF)
C  CHECK FOR END OF FILE
      IF(EOF.EQ.1)RETURN
C  CONVERT TIME READING TO SINGLE PRECISION
      NOWTM=SNGL(TIME)
C  CHECK TO SEE IF IN TIME RANGE REQUESTED
      IF(NOWTM.LT.TM(1))GO TO 1
C  OUTPUT DATA
C  CONVERT TIME TO ACTUAL ELAPSED TIME
2     NOWTM=NOWTM-SNGL(TBEGIN)
      WRITE(10,200)DATA(VNDX),DATA(CNDX),NOWTM
200   FORMAT(11X,F6.1,7X,F6.1,7X,F9.6)
C  READ NEXT BLOCK OF DATA
      CALL GETBLK(NADC,DATA,TIME,EOF)
C  CHECK FOR EOF
      IF(EOF.EQ.1)RETURN
C  CONVERT TIME TO SINGLE PRECISION
      NOWTM=SNGL(TIME)
C  CHECK TO SEE IF TIME RANGE EXCEEDED
      IF(NOWTM.LT.TM(2))GO TO 2
      RETURN
      END
C
C
      SUBROUTINE ACSPEED(NADC)
C
C  ROUTINE WHICH DETERMINES RATE AT WHICH DATA WAS ACQUIRED
C  DURING PRESENT GENERATOR TEST
C
      DIMENSION V1(6),V2(6)
      DOUBLE PRECISION T1,T2
```

```
      INTEGER EOF
C  COMPUTE AVERAGE RATE OF DATA ACQUISITION AND AVERAGE
C  NUMBER OF DATA POINTS PER CYCLE OVER 10 CYCLES
      KNT=0
      KPTS=0
C  INITIALIZE RAW DATA FILE
      CALL GETBLK(N,N,N,2)
C  SET FLAG TO INDICATE BEGINNING OF DATA
      EOF=2
C  GET TWO SETS OF DATA
10    CALL READA(NADC,V1,V2,T1,T2,EOF)
C  CHECK FOR END OF DATA
      IF(EOF.EQ.1)RETURN
C  FIND INITIAL ZERO CROSSING
      IF(.NOT.((V1(4).LE.0.).AND.(V2(4).GT.0.)))GO TO 10
C  INCREMENT POINT COUNT
      KPTS=KPTS+1
C  GET NEXT SET OF DATA
20    CALL READA(NADC,V1,V2,T1,T2,EOF)
C  CHECK FOR EOF
      IF(EOF.EQ.1)RETURN
C  CHECK FOR END OF CYCLE
      IF((V1(4).LE.0.).AND.(V2(4).GT.0.))GO TO 25
C  INCREMENT POINT COUNT
      KPTS=KPTS+1
C  GET NEXT SET OF DATA
      GO TO 20
C  INCREMENT CYCLE COUNT
25    KNT=KNT+1
C  CHECK FOR 10 CYCLES
      IF(KNT.EQ.10)GO TO 30
C  INCREMENT POINT COUNT
      KPTS=KPTS+1
C  GET NEXT SET OF DATA
```

```
      GO TO 20
C  CALCULATE AVE. NUMBER OF POINTS PER CYCLE
30    KPTS=KPTS/10
C  CALCULATE AVE. DATA RATE
      AVRATE=60.*KPTS
C  DISPLAY DATA RATE INFO
      CALL INITT(960)
      WRITE(8,100)AVRATE,KPTS
100   FORMAT(/////,' DATA WAS ACQUIRED AT A RATE OF  ',F10.2,
     1' HERTZ',///,1X,I10,' DATA POINTS PER CYCLE')
C  WAIT FOR OPERATOR ACTION
      WRITE(8,150)
150   FORMAT(//,1X,'TYPE ''GO'' TO CONTINUE')
      READ(7,200)IDUM
200   FORMAT(A2)
      RETURN
      END
C
C
      SUBROUTINE DSSPEED(TM,ZTIMF,NAVE,RMSPK)
      DIMENSION TM(1),RMSPK(1)
      DOUBLE PRECISION ZTIMF
      WRITE(2,100)
100   FORMAT(' DSSPEED IS CURRENTLY NOT IMPLEMENTED')
      RETURN
      END
C
C
      SUBROUTINE REFPLOT(TIME,PEAK)
C
C  ROUTINE PLOTS RMS VOLTAGE AND CURRENT OF PHASE 2 OVER
C  RANGE TIME(1) TO TIME(2)
C  ROUTINE IS CALLED BY DSSPEED AND RMS PLOTS ARE USED
C  FOR REFERENCE
```

```
C
      DIMENSION TIME(1),PEAK(1),RMS1(20),RMS2(20)
     1,PF(3)
      INTEGER EOF
      DOUBLE PRECISION ZTIM1,ZTIM2
C  INITIALIZE DISC READ
      CALL NEADBS(0,2)
C  INITIALIZE EOF OF FILE FLAG (EOF)
      EOF=0
      NADC=5
C  READ FIRST SET OF DATA
1     CALL DREAD(NADC,RMS1,PF,ZTIM1,PERIOD,EOF)
C  CHECK TO SEE IF IN TIME RANGE REQUESTED
      IF(SNGL(ZTIM1).LT.TIME(1))GO TO 1
C  READ NEXT SET OF DATA
5     CALL DREAD(NADC,RMS2,PF,ZTIM2,PERIOD,EOF)
C  CHECK TO SEE IF EOF ENCOUNTERED
      IF(EOF.EQ.1)GO TO 15
C  SET SCREEN TO PLOT PHASE VOLTAGE
      CALL DWINDO(TIME(1),TIME(2),-.5,PEAK(5))
      CALL TWINDO(120,923,580,780)
C  MOVE TO PRECEDING POINT AND THEN PLOT CURRENT POINT
      CALL MOVEA(SNGL(ZTIM1),RMS1(5))
      CALL DRAWA(SNGL(ZTIM2),RMS2(5))
C  SET SCREEN FOR PHASE CURRENT
      CALL DWINDO(TIME(1),TIME(2),-.5,PEAK(2))
      CALL TWINDO(120,923,340,523)
C  PLOT CURRENT VALUES
      CALL MOVEA(SNGL(ZTIM1),RMS1(2))
      CALL DRAWA(SNGL(ZTIM2),RMS2(2))
C  CHECK TO SEE IF REQUESTED TIME RANGE HAS BEEN EXCEEDED
      IF(SNGL(ZTIM2).GE.TIME(2))GO TO 15
C  INTERCHANGE PREVIOUS AND PRESENT DATA VALUES
      ZTIM1=ZTIM2
```

```
      RMS1(5)=RMS2(5)
      RMS1(2)=RMS2(2)
C  GET NEXT SET OF DATA
      GO TO 5
C  PLOT AXIS
C  PLOT VOLTAGE AXIS
15    CALL DWINDO(TIME(1),TIME(2),-.5,PEAK(5))
      CALL TWINDO(120,960,530,760)
      CALL MOVEA(TIME(1),PEAK(5))
      CALL DRAWA(TIME(1),0.)
      CALL DRAWA(TIME(2),0.)
C  LABEL VERTICAL AXIS
      CALL TWINDO(10,1010,570,760)
      CALL VLABL(100,680,'VOLTS',5)
C  LABEL PEAK
      CALL FOUT(20,760,PEAK(5),2)
      CALL HLABL(115,750,'-',1)
C  PLOT CURRENT AXIS
      CALL DWINDO(TIME(1),TIME(2),-.5,PEAK(2))
      CALL TWINDO(120,960,340,520)
      CALL MOVEA(TIME(1),PEAK(2))
      CALL DRAWA(TIME(1),0.)
      CALL DRAWA(TIME(2),0.)
C  LABEL VERTICAL AXIS
      CALL TWINDO(10,1010,290,520)
      CALL VLABL(100,400,'AMPS',4)
C  LABEL PEAK
      CALL FOUT(20,520,PEAK(2),2)
      CALL HLABL(100,510,'-',1)
      RETURN
      END
C
C
      SUBROUTINE DREAD(N,A,V,PF,P,T,EOF)
```

```
      INTEGER A(1),V(1),PF(1),P(1),T(1),EOF
C  INPUT PHASE NUMBER OF DATA SET
5     CALL READ29(K,EOF)
C  CHECK FOR END OF FILE
      IF(EOF.EQ.1)RETURN
C  INPUT RMS CURRENT
      DO 10 I=1,2
      CALL READ29(A(I),EOF)
10    IF(EOF.EQ.1)RETURN
C  INPUT RMS VOLTAGE
      DO 20 I=1,2
      CALL READ29(V(I),EOF)
20    IF(EOF.EQ.1)RETURN
C  INPUT POWER FACTOR
      DO 30 I=1,2
      CALL READ29(PF(I),EOF)
30    IF(EOF.EQ.1)RETURN
C  INPUT PERIOD
      DO 40 I=1,3
      CALL READ29(P(I),EOF)
40    IF(EOF.EQ.1)RETURN
C  INPUT TEST TIME
      DO 50 I=1,3
      CALL READ29(T(I),EOF)
50    IF(EOF.EQ.1)RETURN
C  CHECK FOR SELECTED PHASE
      IF(K.NE.N)GO TO 5
      RETURN
      END
C
C
      SUBROUTINE DINIT
      CALL WRIT29(0,2)
      RETURN
```

```
 1524          END
TOTAL RECORDS WRITTEN =  1525
EXIT
$AUR CI 4
$END  LIST
```

## Appendix C : Display Software User's Manual

### Introduction

This manual describes the user interaction with the display software system. This software allows the user to display the generator test data on the Tektronix 4010 terminal in a number of formats. The user selects the particular format by entering a two character option word. He selects the time range of the display by using the crosshairs of the display terminal. Thus the user selects the format and time range of the data to be displayed. Messages are output with each display directing the user in what display options are available and how to invoke them. The following discussions describe each display format and the associated user interactions.

### Execution of Routine

There are two methods in which to initiate execution of the display software. First, the display software is automatically executed at the completion of the analysis software. In instances where the analysis and display software have been executed previously and a re-display is required, the user can initiate execution of the display software by typing the following commands on the Tektronix keyboard.

```
JOB
EXE DIS LM
```

The routine will respond with the following message.

```
****************************************
*** . TEST DATA AVAILABLE FOR DISPLAY  **
****************************************

**** FOR DATA ACQUISITION RATE INFORMATION
ENTER 'YE'; OTHERWISE, FOR GENERATOR
 TEST SUMMARY PLOT, ENTER 'GO'
```

Sample Rate Display

At this point, both the data file containing the raw test data and the file containing the analysis results have been rewound. Since the data acquisition system can run at several data rates, the user can determine the particular sample rate in effect for this set of test data. The routine accesses the first few cycles of raw test data and counts the average number of data samples per cycle. This information is displayed in the format illustrated in Figure C-1.

When the user has finished with this display, he must respond by entering "GO". This causes the Tektronix screen to be erased and the test summary plot to be displayed.

```
DATA WAS ACQUIRED AT A RATE OF      8800.00 HERTZ

        22 DATA POINTS PER CYCLE

TYPE 'GO' TO CONTINUE
```

Fig C-1. Data Acquisition Rate

Test Summary Plot

The test summary plot is the first data plot displayed whenever the display software is executed. This format displays the rms values of all six data channels versus time. Figure C-2 illustrates the test summary plot.

Each point plotted is averaged over a time range such that only 100 points per channel are displayed. This format displays the entire time range of the test and thus serves as a test summary.

From this initial plot, all other display options can be selected. When the entire display has been plotted and all labelling is complete, the user can produce a hard copy of the display by depressing the COPY switch on the Tektronix keyboard. When the user is finished with this display, he must enter "GO". The following message is then displayed.

```
ENTER PLOT OPTIONS,
FOR LIST OF OPTIONS, ENTER '??'
```

If the user responds with "??", the routine lists a menu of the available display format options. This menu is illustrated in Figure C-3.

Following is a discussion of each display option and its use. The options are discussed in alphabetical order since, in general, they may be chosen in any order.

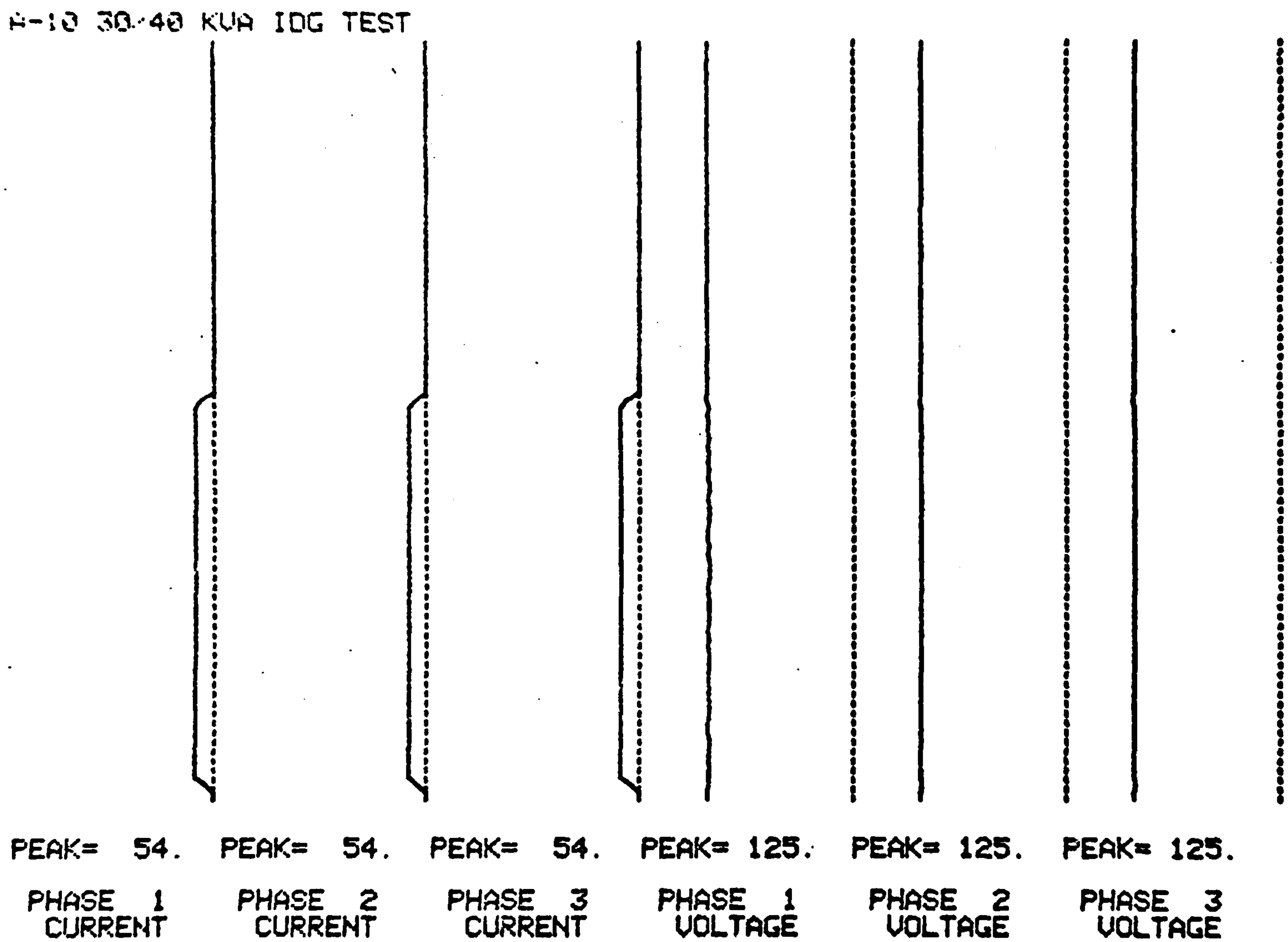



Fig C-2. Test Summary Plot

[illegible] - [illegible] PLOT
[illegible] - [illegible] AND CURRENT PLOT
[illegible] - [illegible]
[illegible] - TEST [illegible] DATA
[illegible] - [illegible] PLOT
[illegible] - [illegible]
[illegible] - [illegible]
[illegible] - TO EXIT DISPLAY

[illegible]
[illegible]
WRITE-UP FOR FURTHER DETAILS.

Fig C-3. Display Format Menu

## Instantaneous Phase Values (CY)

This format presents the instantaneous values of the voltage and current of the phase selected versus the time range selected.

The user selects this display format by entering "CY". The user must now select four parameters which determine how the instantaneous phase value display is to be plotted. First, he must position the appropriate crosshair along the time axis of the current display to the desired starting time. Next the user must enter the phase (1,2, or 3) of generator data to be displayed. Now the user must position the crosshair to select the ending time for the display and set the highlight flag on or off.

The highlight flag determines whether individual data points in the voltage waveform will be highlighted. To set the flag, the user enters a "1"; to reset, a "0". Figure C-4 presents an instantaneous phase value display without highlighting; Figure C-5, with highlighting.

When the user is finished with the display, he enters "GO". The following message is then displayed.

```
FOR REPLOT USING ACTUAL SCALING
ENTER 'RE'; OTHERWISE ENTER 'GO'
```

The initial plot has been scaled to accomodate the largest instantaneous value present over the entire time range. In plots of a lesser time range, this scaling is often not appropriate. By entering "RE", the user causes the previous

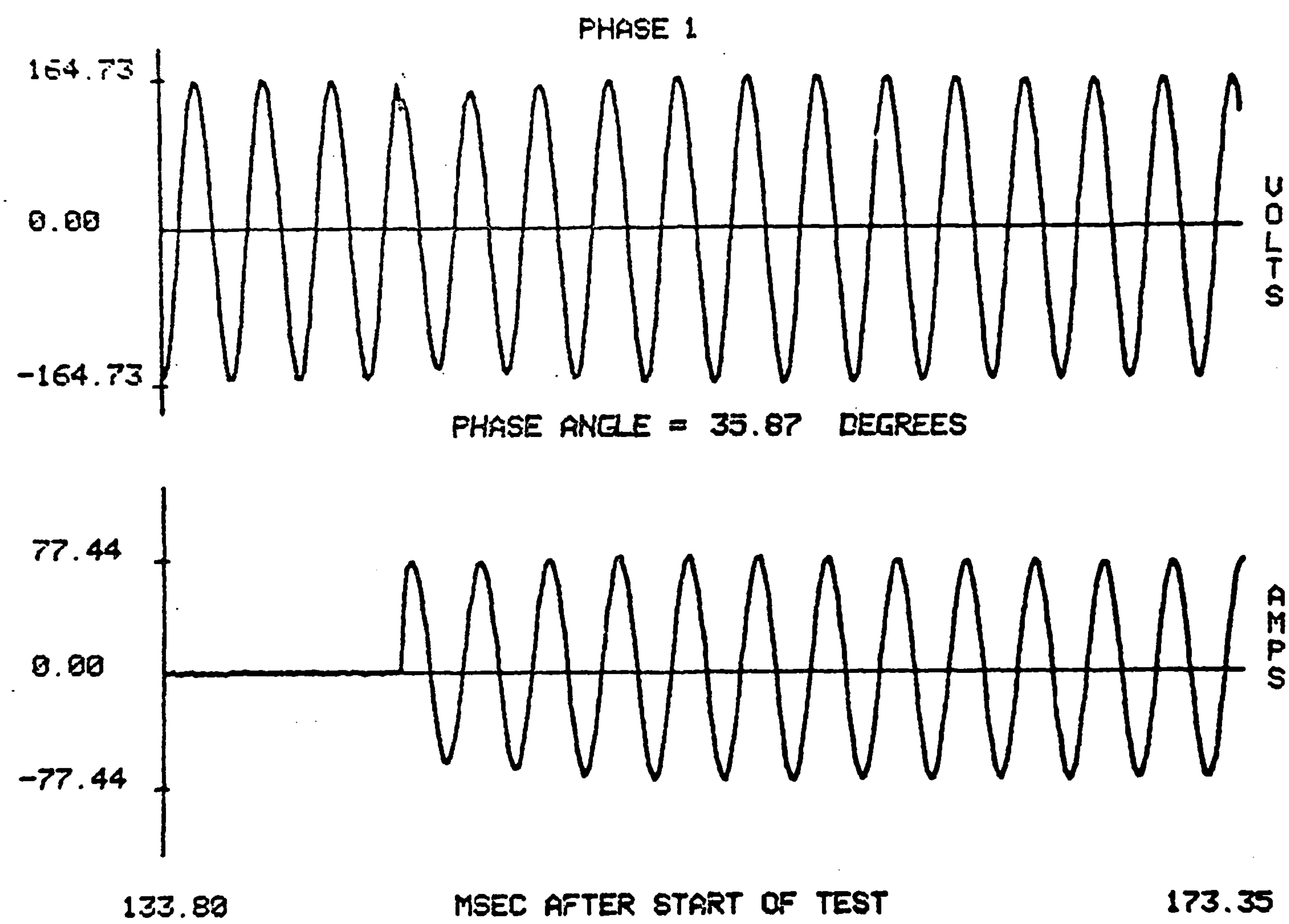



Fig C-4. Instantaneous Phase Values
(without highlighting)

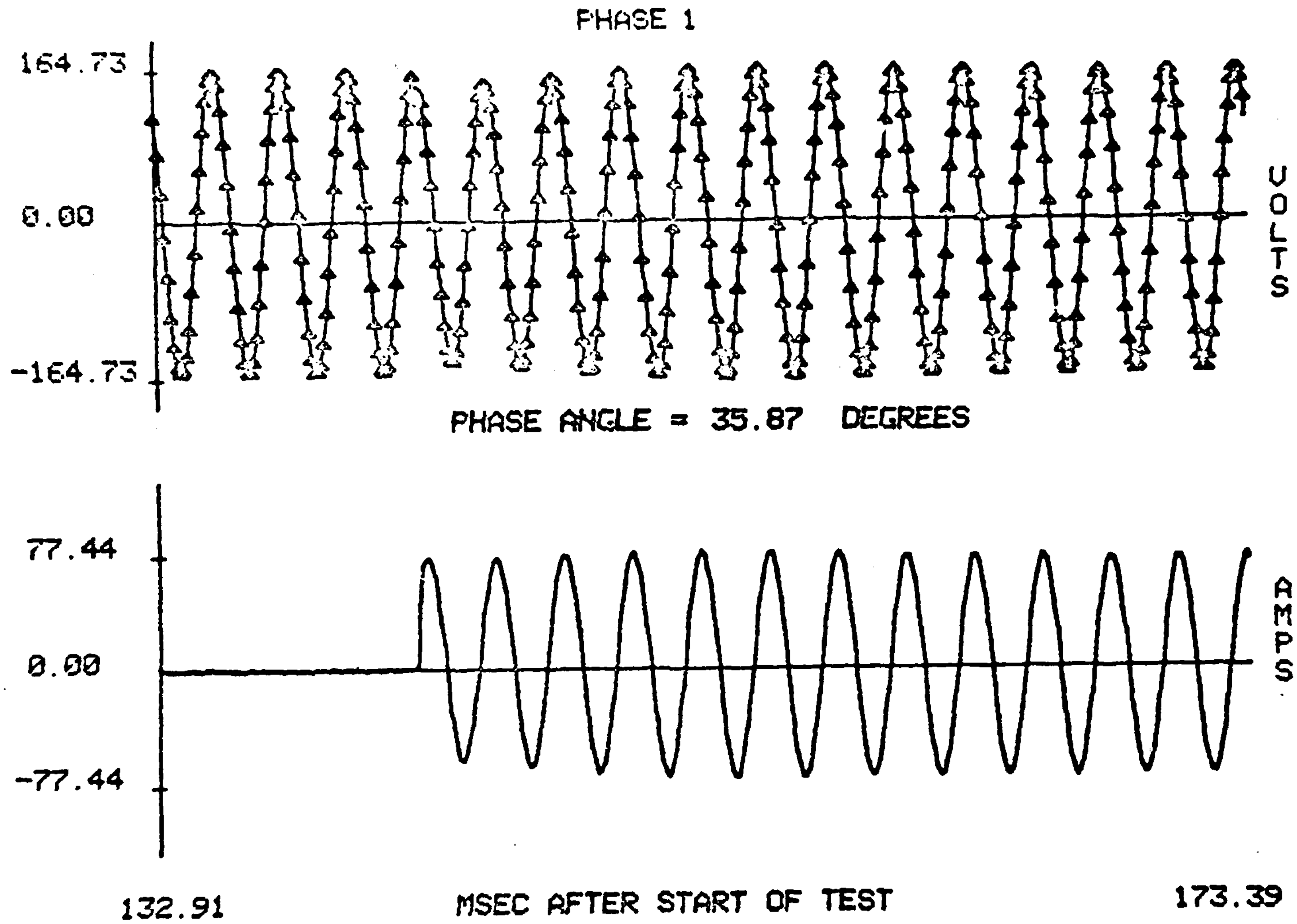



Fig C-5. Instantaneous Phase Values
(with highlighting)

display to be replotted with scaling to accommodate the maximum value over the range displayed.

When the user is finished with the display or if the replot is not chosen, he enters "GO". The following message is then displayed.

```
TO PERFORM FOURIER ANALYSIS
ENTER 'YE'; OTHERWISE ENTER 'GO'
```

By entering "YE", the user directs the software to calculate a Fourier representation of the voltage waveform displayed over the time range and according to the option he now selects.

The user must now select the beginning cycle of the range over which the harmonic analysis will be performed. He aligns the horizontal crosshair to a position just before the beginning of that cycle and enters the number of the phase to be analyzed. To complete the procedure, he must position the crosshair to a later time and strike another key. This last time value and input are not used by the software. The user defines the extent of the analysis later.

The routine will then display the following message.

```
ENTER NUMBER OF HARMONICS TO BE COMPUTED, I2
```

Because the data sampling rate is variable, the user must specify to what extent the harmonic analysis will be valid.

At the usual sampling rate of approximately 8800 hertz, the analysis for 400 hertz waveforms is accurate up to the 11th harmonic. Therefore the user should enter an integer from 2 to 11 in an I2 format.

The routine will then output this message.

```
ENTER NUMBER OF CYCLES OVER WHICH HARMONIC
ANALYSIS WILL BE PERFORMED, I2
```

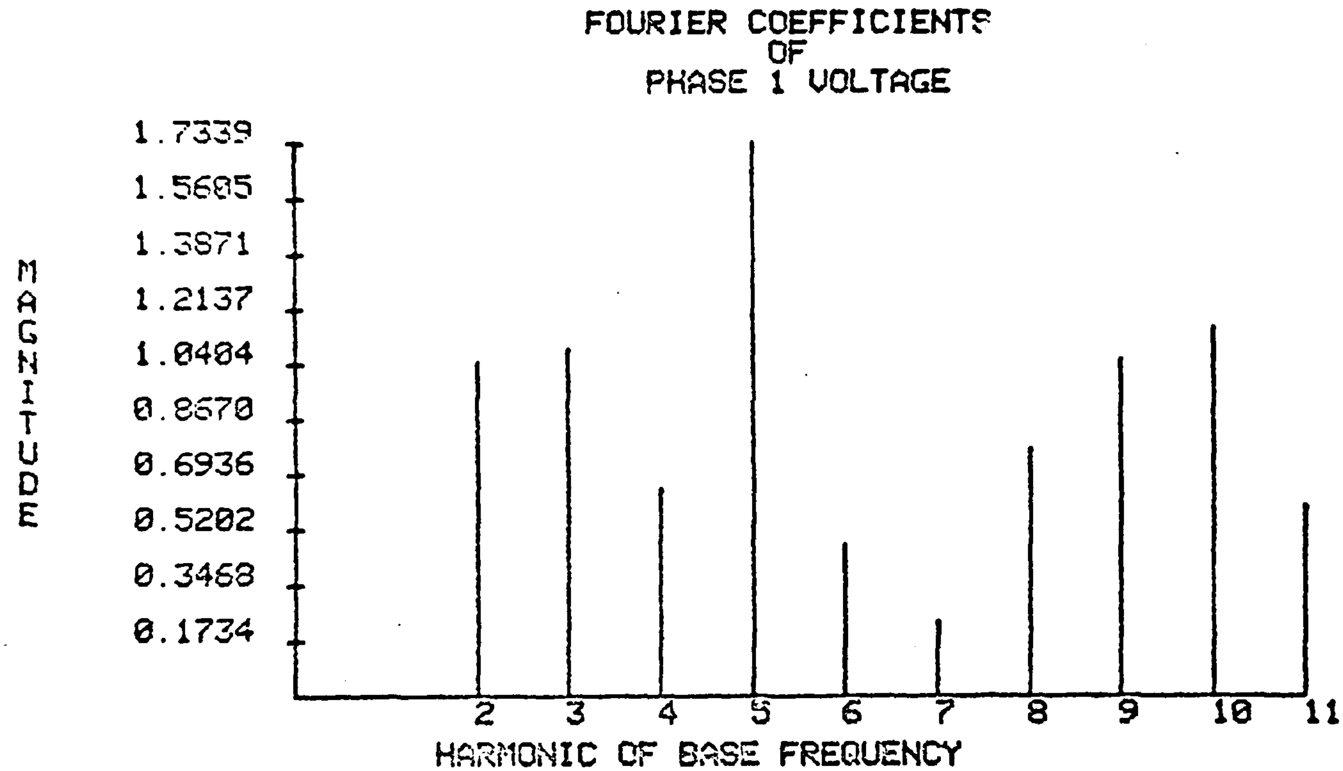
The software can calculate a Fourier representation over a single cycle of the voltage waveform. However in order to compare the results to those produced by a spectrum analyzer, it is usually more useful to perform the computation over several cycles. The user selects a range of from 1 to 60 cycles in an I2 format.

The routine will now compute a Fourier representation for the waveform selected. Figure C-6 is an example of the resulting display. When the user is finished with the display, he enters "GO".

The routine will respond with the following message.

```
FOR PLOT OF WAVEFORM REPRESENTED BY FOURIER COEFFICIENTS
ENTER "OK"; OTHERWISE ENTER "GO"
```

Choosing this option produces a display of the calculated Fourier representation back in the time domain. This plot gives the user confidence in the results of the harmonic analysis. Figure C-7 is an example of this display.




NOTE: BASE FREQUENCY IS 395.52 HZ
MAGNITUDE OF COEFFICIENT = 162.0269
TOTAL HARMONIC DISTORTION = 0.0133
DC CONTENT = 326.9954 MV

Fig C-6. Fourier Representation
(frequency domain)

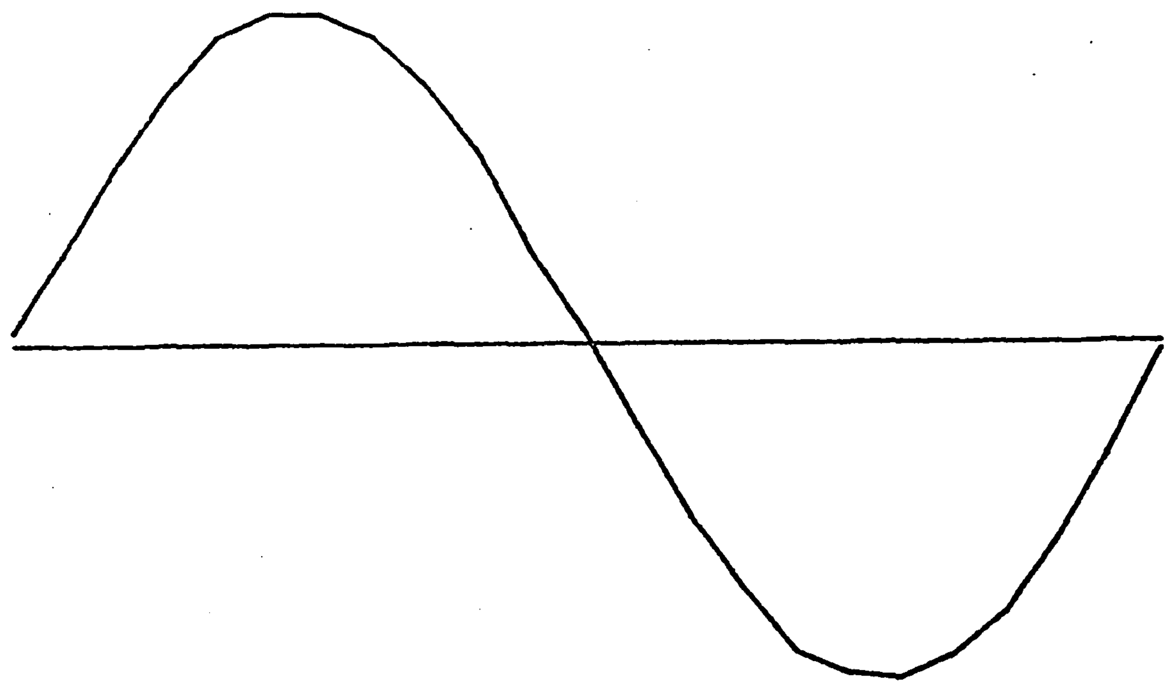


Fig C-7. Fourier Representation
(time domain)

When the user is finished with the time domain plot or if that option is not chosen, he enters "GO". The routine will automatically replot the original test summary plot. This plot must be displayed when a format has just been produced which has no time axis (as in this case) or when a larger time range is desired than the one in the current display.

Frequency Deviation (FQ)

This format displays a plot of the frequency deviation about 400 hertz of the phase selected versus the time range selected. A plot of the rms phase voltage deviation about 115 volts over the time range is also presented.

The user selects this display format by entering "FQ". Next, he must enter the starting time for the display and the phase to be displayed. To do so, he aligns the appropriate crosshair to the position on the time axis which corresponds to the desired starting time and enters the phase number (1,2, or 3). Then he selects the ending time of the display by aligning the crosshair and striking any character. This second character is not used but for clarity should correspond to the phase number.

Figure C-8 presents a typical display of the frequency deviation option. When the user is finished, he must enter "GO". The routine will respond with the following message.

```
FOR REPLOT WITH EXPANDED VOLTAGE SCALE
ENTER 'RE'; OTHERWISE ENTER 'GO'
```

In some instances, the voltage deviation exceeds that allowed by the initial display thus plotting some values "off-screen". By selecting this replot, the voltage scale is expanded to accommodate ' viation.

When the user is finished with the replot or if that option is not selected, the user enters "GO". At this point, the "ENTER PLOT OPTIONS" message is output and the user is allowed to select any of the other possible display options.

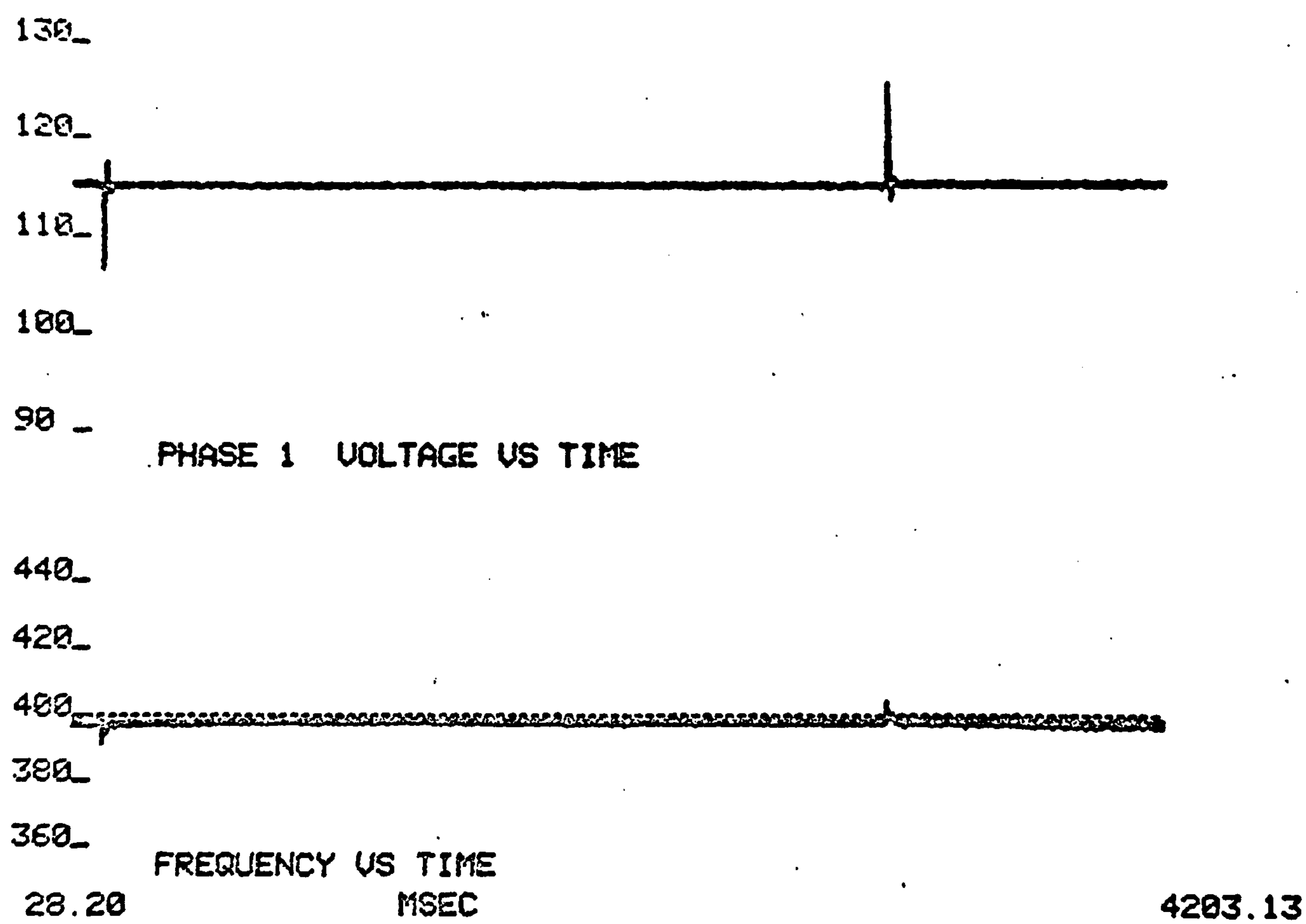


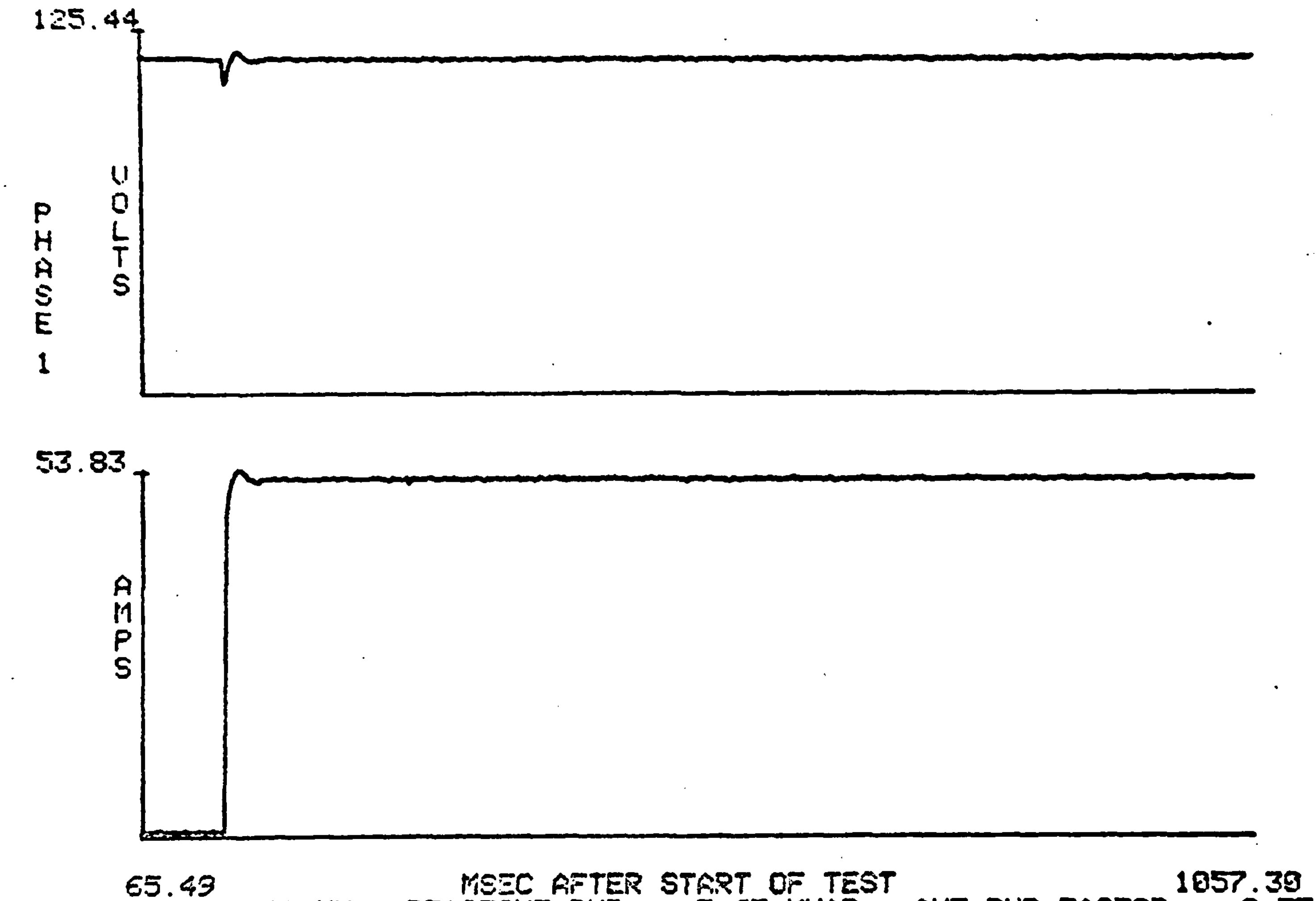

Fig C-8. Frequency and Voltage Deviations

Rms Phase Values (IS)

This format displays the rms voltage and current values of the phase selected versus the time range selected. Several power calculations are performed over the time range and their results are also displayed.

The user selects this display format by entering "IS". He then positions the crosshair along the time axis of the current display to select the starting time for the rms display and enters the phase (1,2, or 3) to be displayed. Next, he positions the crosshair to select the ending time and strikes another character. Again this second character is not used but it is recommended that the phase number again be entered.

Figure C-9 presents a typical plot of rms values. When the user is finished with this display, he enters "GO". Again, the "ENTER PLOT OPTIONS" message is output and any of the display options can now be selected.




REAL PWR = 4.20 KW; REACTIVE PWR = 3.67 KVAR; AVE PWR FACTOR = 0.75
AVE RMS VOLTAGE = 114.96 VOLTS; AVE RMS CURRENT = 48.55 AMPS

Fig C-9. Rms Phase Values

Instantaneous Phase Values Table (PC)

This format displays a table of instantaneous voltage and current values and the corresponding test times of the phase selected over the time range selected.

The user selects this option by typing "PC". Then the user positions the crosshair along the time axis of the current display to select the starting time for the table and then enters the phase (1,2, or 3) to be displayed. Then he selects the ending time and strikes any character. Again, this second character is not used but for clarity should be the phase to be displayed.

The routine then begins outputting the table of instataneous values. The routine lists a screen full of values, issues a beep allowing the user time to make a hard copy. When the user is finished with the current display, he strikes any two characters which causes the routine to erase the screen and output the next screen full of values.

Figure C-10 presents a typical display of a table of instantaneous values. When the user is finished with the last screen full of values, he enters "GO". Since this display format has no time axis, the test summary plot is again produced automatically

## PHASE 1

| VOLTAGE | CURRENT | TIME |
|---|---|---|
| 149.8 | 38.6 | 0.379339 |
| 161.0 | 53.3 | 0.379452 |
| 160.0 | 65.2 | 0.379565 |
| 148.4 | 72.5 | 0.379678 |
| 125.0 | 73.8 | 0.379791 |
| 90.0 | 66.9 | 0.379904 |
| 48.7 | 57.5 | 0.380017 |
| 2.5 | 42.1 | 0.380130 |
| -43.2 | 26.1 | 0.380243 |
| -82.1 | 5.5 | 0.380356 |
| -118.5 | -17.2 | 0.380469 |
| -147.2 | -33.4 | 0.380582 |
| -160.4 | -53.5 | 0.380695 |
| -160.4 | -65.6 | 0.380808 |
| -151.1 | -72.9 | 0.380921 |
| -127.8 | -75.3 | 0.381034 |
| -94.7 | -70.6 | 0.381147 |
| -54.9 | -60.9 | 0.381260 |
| -8.7 | -45.7 | 0.381373 |
| 38.5 | -29.7 | 0.381486 |
| 76.9 | -10.5 | 0.381599 |
| 114.8 | 13.3 | 0.381712 |
| 144.5 | 33.8 | 0.381825 |
| 159.5 | 53.1 | 0.381938 |
| 161.0 | 62.5 | 0.382051 |
| 152.7 | 70.6 | 0.382164 |

Fig C-10. Instantaneous Phase Values Table

General Plot of Instantaneous Values (PL)

This display format is similiar to the plot of instantaneous phase values (CY) except that the user can select a plot of the values of any two data channels.

The user selects this option by entering "PL". Next, the user positions the crosshair to select the starting time for the display and enters the number of the data channel (1-6) to be plotted in the upper portion of the display. Then the user positions the crosshair to select the ending time for the display and enters the number of the data channel to be plotted in the lower portion of the display.

Figure C-11 presents a typical display of this type of instantaneous values plot. When the user is finished with the display, he enters "GO". The "ENTER PLOT OPTIONS" message is output and the user can now select any of the other display options.

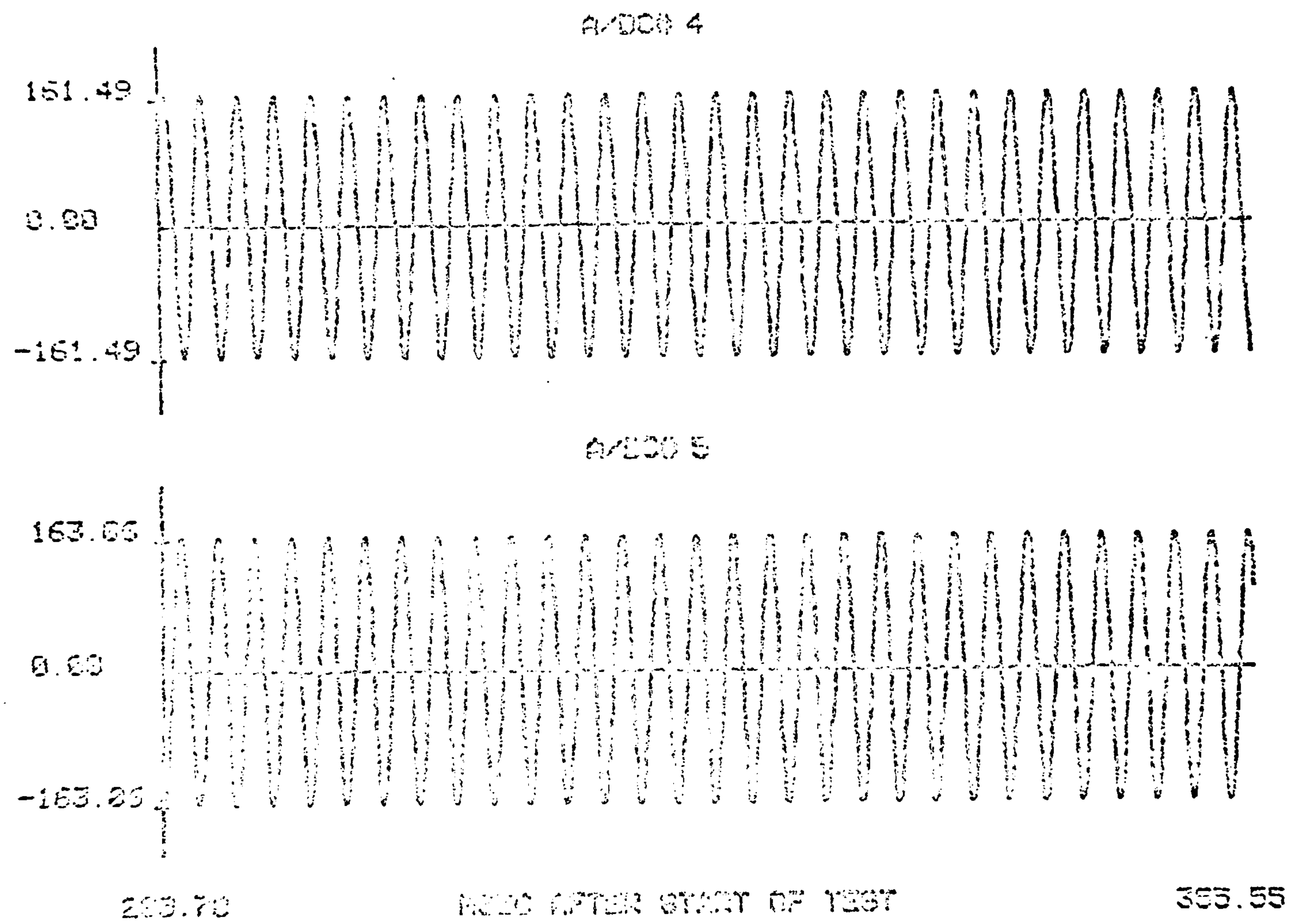



Fig C-11. Instantaneous Values

Rms Phase Values Table (PR)

This format presents a table of rms voltage values, rms current values, power factors, frequency values, and the corresponding test times.

The user selects this option by entering "PR". Next, the user positions the crosshair along the time axis of the current display to select the starting time for the table and enters the phase (1,2, or 3) to be displayed. Then he positions the crosshair to select the ending time and enters the number of cycles over which to average the instantaneous values before display (1-9). Normally no averaging is necessary, but in some instances this averaging feature is useful.

The output paging described with the instantaneous values table is also used with the rms values table. Figure C-12 presents a typical display of this type. When the user is finished with the last screen full of rms values, he enters "GO". Again since this format has no time axis, the test summary plot is automatically produced.

PHASE 1

EACH ENTRY REPRESENTS AN AVERAGE OF 1 READINGS

| RMS VOLTAGE (VOLTS) | RMS CURRENT (AMPS) | FREQUENCY (HZ) | PF | TIME (SEC) |
|---|---|---|---|---|
| 115.1 | 0.7 | 397.9 | -.066 | 0.121976 |
| 115.0 | 0.7 | 397.5 | -.009 | 0.124489 |
| 114.7 | 0.7 | 397.2 | -.023 | 0.127005 |
| 114.6 | 0.9 | 397.7 | 0.015 | 0.129522 |
| 114.7 | 0.7 | 393.1 | -.119 | 0.132037 |
| 114.6 | 0.6 | 397.2 | -.143 | 0.134549 |
| 114.8 | 0.6 | 397.4 | -.051 | 0.137057 |
| 114.7 | 0.7 | 397.7 | 0.032 | 0.139583 |
| 105.4 | 46.7 | 391.3 | 0.723 | 0.142093 |
| 107.8 | 53.0 | 395.4 | 0.817 | 0.144653 |
| 112.5 | 52.0 | 395.1 | 0.819 | 0.147182 |
| 115.6 | 53.2 | 395.6 | 0.819 | 0.149785 |
| 117.0 | 53.8 | 394.7 | 0.818 | 0.152234 |
| 117.4 | 53.8 | 395.2 | 0.817 | 0.154768 |
| 116.8 | 53.4 | 394.6 | 0.816 | 0.157298 |
| 116.0 | 53.0 | 395.8 | 0.818 | 0.159833 |
| 115.1 | 52.5 | 395.6 | 0.820 | 0.162359 |
| 114.4 | 52.4 | 395.4 | 0.814 | 0.164887 |
| 114.2 | 52.1 | 397.3 | 0.818 | 0.167409 |
| 114.4 | 52.0 | 397.4 | 0.819 | 0.169926 |
| 114.4 | 52.3 | 397.0 | 0.819 | 0.172443 |
| 114.7 | 52.5 | 397.7 | 0.820 | 0.174962 |
| 114.9 | 52.5 | 397.8 | 0.820 | 0.177476 |

Fig C-12. Rms Phase Values Table

Quick Replot (QK)

In instances where the current display format has no time axis from which to select starting and ending times or when a larger time range is desired, the user must select a replot of the original test summary by entering "QK". Discussion of this display format has been presented earlier.

Exitting Display Software

When all desired displays of generator test data have been produced, the user exits the display software by answering the "ENTER PLOT OPTIONS" message with "$$".

# VITA

Philip Glen Gaberdiel was born on 31 May 1952 in Elk City, Oklahoma. He graduated from high school in Hobart, Oklahoma in 1970 and attended the University of Oklahoma, Norman, Oklahoma, until early 1972. He enlisted in the United States Air Force in 1972 and was accepted for the Airman's Education and Commissioning Program in 1973. He then returned to the University of Oklahoma and received the Bachelor of Science in Electrical Engineering in May 1976. After his commissioning in September 1976, he was assigned to the Aerospace Power Division of the Aero Propulsion Laboratory at Wright-Patterson, AFB, Ohio. Since then he has worked as project engineer in the development of the Generator Test Facility and has pursued the class work requirements for the Computer Systems degree at the Air Force Institute of Technology on a part-time basis.

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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

400 Hertz Waveforms

Aircraft Electrical Generators

Electrical Transients

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A software system was specified which would derive the performance measures of MIL-STD-704B from the test data provided by the Generator Test Facility. This analysis software system was then designed and implemented. Accuracy tests on the system demonstrated that very precise measurement of generator performance can be obtained.

A software system was also designed and implemented to display the analysis results to the user. The display system employs a Tektronix 4010 terminal in

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) an interactive mode to present the data. The user, therefore, selects the particular display and time range to be presented.

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